

COMBUSTION

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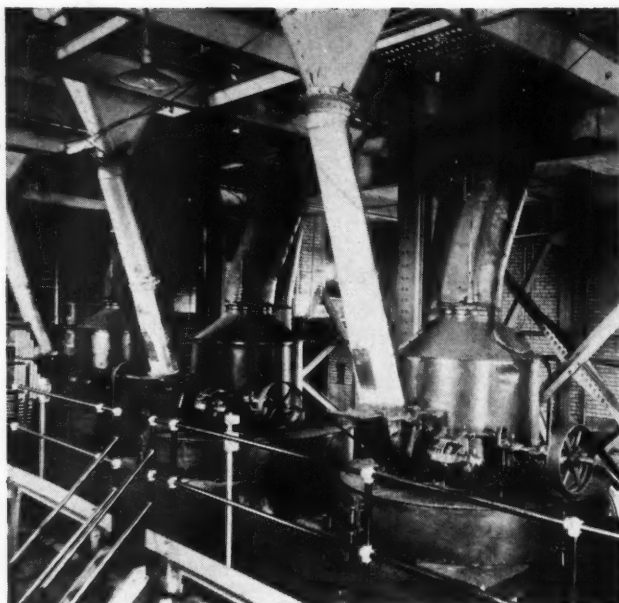
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High and Net Heat Values of Fuels By HENRY KREISINGER

Relation of Salt Water Condenser Leakage to Boiler Water Conditioning By A. H. MOODY

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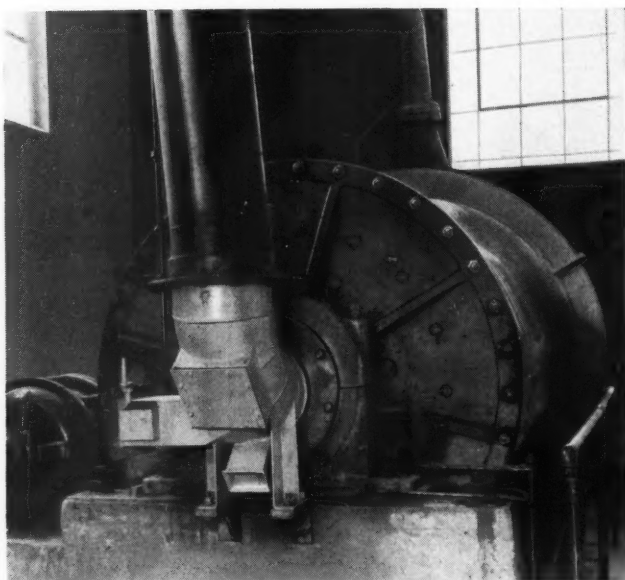
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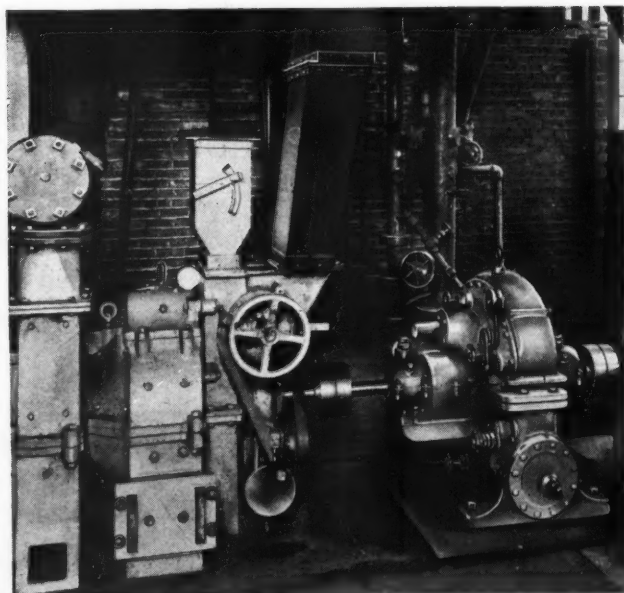
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CHARLES McDONOUGH
Business Manager

CARL STRIPE, *Editor*

H. STUART ACHESON
General Representative

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COMBUSTION

Vol. 2

August, 1930

No. 2

Manufactured Coal



H. W. BROOKS

COAL is the only product man wrests from nature whose lack could wreck our present day civilization. It is the one raw material for which there is no known substitute. Oil or gas can be made from coal, but the process is irreversible. Without coal,

our combined known resources of American fuels recoverable by present methods would last less than three years.

Is it not then an anomolous and even dangerous situation when not only in America but in all the major coal producing nations of the world the coal industry finds itself economically prostrate? No basic industry has seen such a high percentage of business mortality nor such narrow profit margins.

Industries rarely become economically stable which content themselves with the production of raw materials only. Freedom from recurring variations of the business cycle result only when manufacturing costs materially exceed raw material costs. Cotton and steel are industries which have seen this and realized economic salvation. From manufactured cotton last year, cotton-growing North Carolina paid the third largest income tax of any American State. Copper, sugar, silk and wheat represent the converse—raw materials industries yet uncoupled to their natural manufacturing functions and hence continuing victims of recurring cyclic upsets.

Far sighted coal men today are realizing that their economic salvation lies in production of a beneficiated product. Operators who before the war lost interest after coal was loaded on cars, are today thinking in terms of manufactured coal in the form of steam-produced power, temperature-regulated heat, manufactured gas, tar oils and a thousand other by-products of coal. In France and Germany,

coal operators have for years been numbered amongst these nations' largest power producers. In England and Germany, coal companies have invested millions in by-product processing at both high and low temperatures producing manufactured gases, oils and other by-products. In America, the challenge of gas and oil to coal's high priced sized coal market in the domestic, commercial and small industrial field has been met by a rapidly growing small and domestic stoker industry furnishing a new cleanliness and convenience with a tremendous appeal. This most recent of coal efforts has largely been instituted, fathered and financed by the coal industry. Through it both anthracite and bituminous operators have benefited in large measure. Both today find it their strongest weapon against oil and gas competition.

More than 100 large coal operators now employ experienced combustion engineers to co-operate in serving their customers more intelligently. Today the selection of the most suitable and most economical fuel is becoming a matter of as much concern to the coal purveyor as it is to the user. It is to the interest of the industry that this service be extended.

Fuel research expenditures, largely financed by the coal industry or its affiliates, today total more than five millions annually. In this movement the Anthracite Operators' Association has already contributed liberally, while the bituminous operators through the National Coal Association have under consideration an even more ambitious research program.

Old King Coal remains the benevolent monarch of a changing kingdom. Sorely beset by his enemies, he is nevertheless one of the few present day monarchs whose future is assured through the principle of the survival of the fittest.



Consulting Engineer, New York

EDITORIAL

"The Conditions at My Plant Are Different"

THE majority of industrial plant owners and operators have one failing in common.

Each believes his own steam plant conditions to be peculiar to his particular plant or, at least, to his particular industry.

The steel plant engineer explains, "We have a heavy rolling mill load."

The paper mill executive points out, "It's our process steam demand that makes our conditions unusual."

The food products plant has its "cooking load," and the mine operator refers to his "hoisting load."

In reality, the boiler plant can recognize only two load conditions; the pressure and temperature of the steam; and the rates at which it is required.

There are no "rolling mill loads," "cooking loads" or "hoisting loads" in the boiler house—they are all steam demands.

In this connection, industrial plant owners may profitably adopt the attitude of our public utility engineers. Examples of every conceivable combination of pressure and load are found in central station practice—pressures from less than 100 lb. up to 1400 lb. per sq. in.; boilers loafing along at one-third rating and others operating hour after hour at ratings above 500 per cent; steady loads and widely fluctuating loads; high load factors and low load factors. Despite the fact that in central station practice these conditions vary between wider limits than they do in industrial practice, the central station engineer has long since learned to reduce all steam demands to the common denominators of pressure, temperature and rate of flow. He is thus able to compare performance figures which are obtained under widely different conditions and to apply to his own needs the successful experience of others.

We oftentimes hear it said that a certain boiler is "a good steel mill boiler." If it is, it is also a good boiler for any other industry, provided the pressure, load and operating conditions are the same.

Perhaps a certain type of stoker has proven satisfactory in many plants of the paper industry. It earns a reputation as a good stoker for paper mill conditions. It will be equally satisfactory in any other industry with identical conditions of application and operation.

Too often the industrial plant engineer is hesitant about accepting and applying performance data which are obtained under conditions unlike his own,

particularly if they are secured from some other industry. He peremptorily dismisses such information as irrelevant and crawls into his shell, hiding behind that hackneyed excuse—"The conditions at my plant are different."

Let him keep in mind that steam leaving the boiler plant does not know whether it is to roll steel, hoist coal, cook tomatoes or spin a turbine.

What Is High Pressure? —Low Pressure?

STEAM pressures already adopted for commercial use in America range from a fraction of a pound to 1800 pounds per square inch. While the vast majority of our steam plants operate at pressures well inside of these limits, they are all classified as either high pressure or low pressure, these terms representing each extreme end of the scale without respect to the exact location of the dividing line between the two. Any particular pressure within the range is arbitrarily classified as either high pressure or low pressure.

Obviously, we have been guilty of loose terminology.

One difficulty in establishing definite gradings of pressures is that each pressure considered is relative and may be either high or low depending upon some other pressure with which it is compared.

An industrial plant owner having two plants may operate one at 50 pounds pressure to meet certain conditions, while the other may operate at 300 pounds. To that owner, the second plant will be his high pressure plant.

A public utility may operate two plants, one at 300 pounds and the other at 600 pounds. Here the 300 pound plant becomes a low pressure plant by comparison. If a third installation is made and a pressure of 1200 pounds or higher is selected, the confusion increases.

Some years ago, when the range of steam pressures in commercial use covered only a few hundred pounds, the need for a classification of pressure was not pressing. Today, that need is recognized and, in the future, with every indication of the eventual use of pressures approaching the critical limit of 3200 pounds, the adoption of a standardized scheme of classification is almost imperative.

In an early issue of COMBUSTION, two authors, who are recognized as authorities in their particular fields, will make an important contribution to this subject of steam pressure classification. Their reasons for establishing each limit are rational and the nomenclature recommended is simple and easily applied.

Relation of Salt Water Condenser Leakage to Boiler Water Conditioning

By Dr. A. H. MOODY

Chief Chemist, The United Electric Light and Power Co., New York

IN the April issue of COMBUSTION a high pressure system of boiler water conditioning was described by A. A. Markson. His system aimed not only to prevent scale deposits on the heating surface of boiler tubes but also avoid

wet steam, economizer deposits, and corrosion. In the May issue of COMBUSTION a discussion by Dr. R. E. Hall of the previous paper called attention to the seriousness of condenser leakage when salt water is used for circulation. The present article will take up in more detail this phase of the subject and its relation to boiler water conditioning.

When we have the ideal condition of no salt water condenser leakage, the treatment of boiler water is comparatively simple. This is true because the composition of make-up water is fairly constant and its rate of entering the system can be fairly well estimated. Boiler water treatment can then be proportioned in exact accordance with the quantity of make-up water, regardless of whether the make-up is a large or small percentage of the total feedwater. With salt water condenser leakage, the control of the boiler feedwater treatment is made much more difficult.

The problem is complicated by two facts: the first is that it is impossible to foretell the rate at which a contaminating water will enter the system; the second is that the circulating water, especially when it is sea water, contains a high concentration of undesirable elements. Bicarbonate, chloride and calcium are the chief offenders. Bicarbonate is deleterious because it is largely decomposed in the boiler with formation of caustic and carbon-dioxide, the latter passing over into the steam lines with corrosive properties. As Dr. Hall has pointed out, and as Mr. Markson's experience has shown, uncontrolled caustic in the boiler water causes bad boiling conditions and wet steam. Chloride entering the system through the condensers assists in increasing the total dissolved solids, thus increasing the electrical conductivity of the water and consequently speeding up electro chemical corrosion tendencies. Calcium is a principal component of adhesive boiler

Salt water condenser leakage adds considerable difficulty to the problem of proper conditioning of boiler feedwater. Dr. Moody ably discusses this particular phase of the problem and offers helpful suggestions as to ways and means of minimizing such leakage, detecting its occurrence and counteracting its deleterious effects. This article represents a valuable contribution to the series published in COMBUSTION on the subject of feed-water treatment.

scale and requires an increase in boiler treatment to counteract its bad effects. With high dissolved solids entering the boiler feed water system, it is necessary to increase the amount of blow-down on the boiler, with consequent heat loss,

in order to maintain the total dissolved solids in the boilers below the prescribed maximum.

When the make-up is small, condenser leakage causes a marked change in the composition of the feedwater. From the data in Table I it can be shown that a .03 per cent condenser leakage will admit to the feedwater as much calcium as a 3 per cent make-up water, thus doubling the calcium content and requiring twice as much chemical in the boiler feedwater treatment to precipitate the calcium. In the case of chlorides only a .0001 per cent leakage is required to equal that of a 3 per cent make-up water. Looking at it from another point of view, should the condenser leakage run as high as .5 per cent the increase in calcium would be sixteen times a calcium equivalent of 3 per cent make-up water or five thousand times the chloride, and about a thirty-fold increase in total dissolved solids. Under these circumstances it is obvious that exact control of boiler water composition is exceedingly difficult.

TABLE I

	1 Croton (a) Water p.p.m.	2 East River Water p.p.m.
Bicarbonate (HCO_3)	36.6	122
Sulphate (SO_4)	8.2	485
Chloride (CL)	5.0	14500
Nitrate (NO)	0.6	....
Silica (SiO_2)	9.0	13
Iron and Aluminum Oxides ($\text{Fe, AL}_2\text{O}_3$)	....	204
Calcium (Ca)	9.6	1002
Magnesium (Mg)	3.5	140
Sodium (Na)	3.2	8350
Potassium (K)	0.4	....

(a) Furnished by Bureau of Water Supply, Frank E. Hale, Director of Laboratories.

With modern boiler design and operation, the nature and quantity of dissolved and suspended solids in the boiler water is becoming an increasingly important matter. There is a growing tendency to

operate boilers at higher ratings and to build boilers with normally high capacity, witness: recent installations of over 1,000,000 lb. steam per hour, per boiler. Old boilers are being revamped with increased heating surface by use of water walls and larger stoker capacity without changing the size or design of drum and steam spaces. Such conditions aggravate the problem of wet steam.

When operating boilers with high water level in

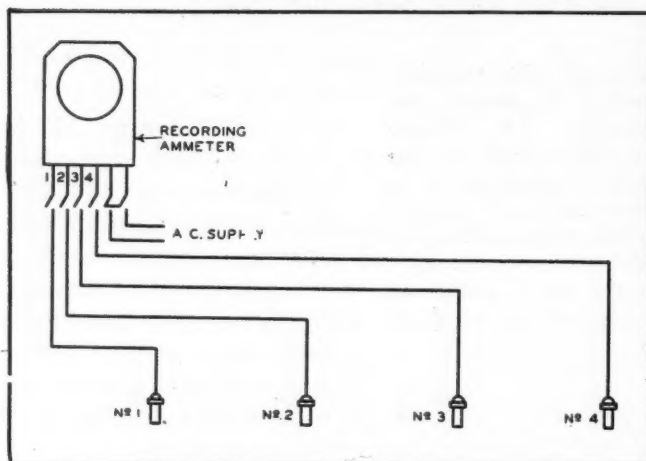


Fig. 1—Ammeter method of detecting condenser leakage

the drum, coupled with high rating and insufficient steam spaces to allow dropping out of the entrained moisture, the quality of the boiler water, which is the only variable left, must be carefully controlled to avoid heavy carryover. Even with only .3 per cent moisture in steam a plant producing 3,000,000 kw-hr. per day from a boiler water containing 5,000 p.p.m. (300 grains per gal.), total solids would have a theoretical total carryover into the steam lines and turbines of over 500 lb. of solid matter per day which must either deposit in the steam lines or turbines or be washed through into the condensate. Such solids have a tendency to deposit where there is a sudden reduction in velocity of the steam and

TABLE II
ANALYSIS OF SCALE ON STEAM VALVES

	No. 4 Valve	No. 5 Valve
Silica and Insol.....	4.71	1.54
Sodium Chloride.....	52.35	46.97
Sodium Sulphate.....	17.65	18.40
Sodium Carbonate.....	17.35	19.22
Sodium Phosphate (Tri).....	6.08	8.14
Magnesium Oxide.....	.59	.16
Iron and Aluminum Oxides.....	.87	.75
Sodium Bicarbonate.....	.33	4.20
	99.93	99.38

may cause trouble in superheaters, dividing valves and throttle valves.

Table II gives the analyses of two deposits caused by defective drum baffling and taken from steam dividing valves. The materials were very hard and brittle and at times accumulated on the valve seat to such an extent that it was impossible to close the valve completely. The scale consists of about 50 per cent

sodium chloride mixed with 15 per cent to 20 per cent each of sodium sulphate and sodium carbonate. All of these constituents are derived from salt water condenser leakage in large quantities.

Condenser leakage into the boiler feedwater system can be reduced considerably by the vigilance and the care of the operating men. When a turbine has been idle there is considerable accumulation of salt in the condenser by gradual seepage through small leaks. This salt should be completely washed out before cutting in the condensate to the feed water line. Consequently, it is good practice to divert condensate overboard until the turbine goes on the line. This insures a thorough washing out of the condenser and the small loss of condensate is more than worth while. As a means of checking the salt content of the condensate, a sample of water may be taken from the hotwell and tested chemically by an instructed member of the operating force. The method is as follows: a few drops of potassium chromate solution (5 per cent) is added to 25 cc. of condensate water and exactly two drops of 2 per cent silver nitrate solution is added from a medicine dropper. If the red color does not persist after stirring the solution then the salt content of the condensate is too high. The hotwell water should therefore be continued overboard until a tested sample shows no excessive salt concentration.

Several electrical methods have been devised to give a continuous record of the salt content of the hotwell condensate. Some incorporate an alarm system to warn the operator of excessive salt conditions. The general principle made use of in most of these methods is that the electrical conductivity or ohmic resistance between two electrodes placed in the water varies with the concentration of salt in

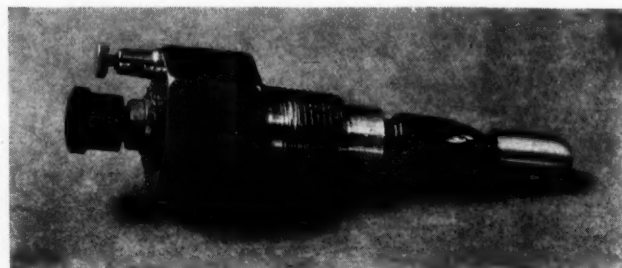


Fig. 2—Conductivity cell plug

the water. Exact measurement of the salt concentration is limited by various errors in the methods. These errors are caused by secondary effects in the electrodes, temperature changes of the water, and other impurities in the condensate. Various schemes have been introduced in order to minimize these errors. One method utilizes the principle of the Wheatstone Bridge with the object of compensating for variations. A much simpler means of measuring salt concentration is that by the ammeter method.

The ammeter method makes use of the electrical principle of ohmic resistance already referred to.

The electrical circuits are shown in Fig. 1. This figure indicates how four conductivity cell plugs may be connected in parallel to one recording ammeter to give a continuous record of any salt changes at four different points. Any increase in salt at any one of the four locations will produce a reading above normal. To determine which one is reading high, each of the cells is cut out by means of switches until the troublesome one is located. Fig. 2 shows a recent

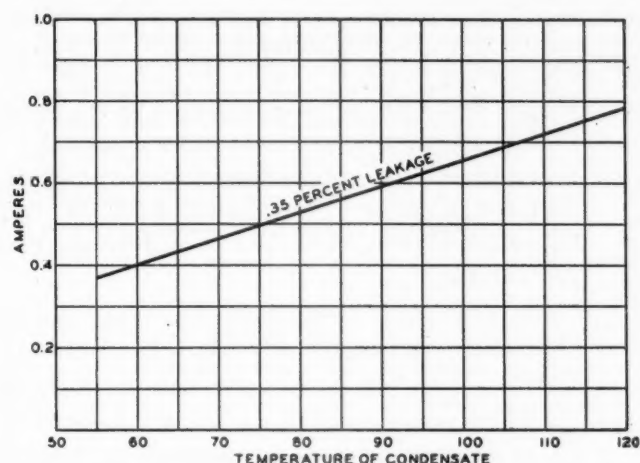


Fig. 3—Error in readings due to temperature of condensate, assuming a .35 per cent leakage

type of conductivity cell plug which has been recommended. The curve in Fig. 4 gives the relationship between ampere reading and per cent condenser leakage. Although this method is subject to all the errors previously mentioned, this does not prevent it from being a handy system for following changes in salt content in the hotwell condensate and even at other parts of the system. The temperature of the condensate causes a slight error in the readings and the magnitude of this error is shown in Fig. 3, assuming a .35 per cent leakage. Either alternating current or direct current can be used in this method. Some preference is given to alternating current due to the fact that a transformer may be interposed to separate the ground electrodes from the supply current. A unique application of a recording conductivity meter has been recommended for locating leaks in the condenser after it is taken out of service. The method is as follows: the condenser is filled with salt water and the water level is slowly lowered until the horizontal row of tubes containing the leak is uncovered. At this point the reading on the recording conductivity meter will drop back to normal and this row may then be examined for leaks.

Leaks may occur either in the tubes themselves or in the packing at the end of the tubes. Three general types of packing are in general use; fibre packing, metal packing, and corset-lace or wicking packing. The use of wicking seems to be more popular than either of the other two types of packing. This is probably due to less trouble with leakage even though the labor of packing may be a little higher.

Some operators find trouble with fibre packing drying out when the condenser is out for repairs on the unit. To avoid this the condenser is kept full of water except when it is being worked on. Some operators find it advisable to tighten-up on fibre packing in the spring when changing from winter to summer conditions. Proper packing of the tubes is essential to prevent salt water condenser leakage.

Troubles from salt water condenser leakage may be postponed considerably by taking care to insure long life for condenser tubes. In the first place the composition of Admiralty tubes should conform exactly with the specifications laid down by the American Society for Testing Materials. The chemical composition prescribed is as follows:

Copper.....	not less than	70.00 per cent
Tin.....	0.90 to	1.20 " "
Lead.....	not over	0.075 " "
Iron.....	not over	0.06 " "

Short life of some condenser tubes in service has been traced directly to a deficiency of tin in the mix and variation in the copper content. Analyses of tubes that failed with 3 to 8 months' service was as follows:

	No. 1	No. 2	No. 3
Copper.....	67.56	64.65	62.40
Zinc.....	32.31	35.00	37.45
Tin.....	none	.22	none
Iron and Oxides.	.11	.13	.10
Lead.....	trace	trace	trace

A typical life curve of condenser tubes using East River salt water is shown in Fig. 5. Very little trouble is experienced during the first 36 months of

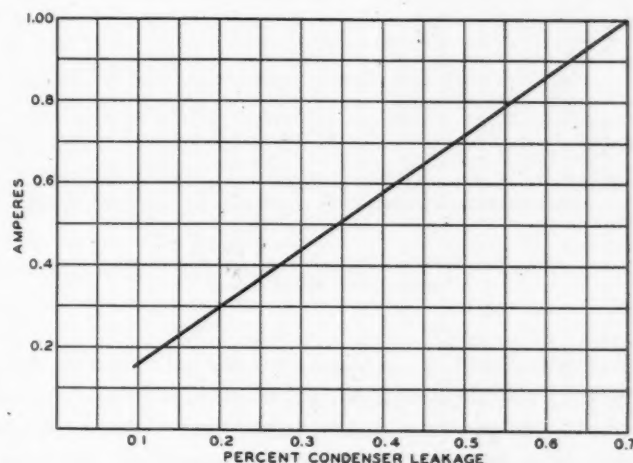


Fig. 4—Relationship between ampere reading and per cent condenser leakage

life. In this case only 100 tubes on a 10,000 tube condenser had required plugging. After the third year, however, closer check must be made on the tubes as leakage becomes much more frequent.

Various schemes have been proposed in attempts to extend the life of tubes. Failures frequently occur at the inlet end due to erosion or vortex action. Several companies make use of special ferrules or

wearing tips about 6 in. long to eliminate this trouble. One operator estimates that wearing tips will last in service for five years and will at least double the life of condenser tubes. Where considerable dissolved oxygen is found in the circulating water, vortex action at the inlet end of the tube seems to be aggravated. Mechanical devices have been recommended to reduce the entrance loss and thereby prevent eddying currents in the condenser tubes. Reversing the tubes end for end, after they have been in service for some time, has been practiced in order to obtain longer wear from the tubes. It has also been proposed to allow the tube to extend several inches at the exit end and when the inlet end fails to cut off the tube to standard length and put it back in the condenser.

Attempts to make use of the principle of counter electromotive force by means of applied electrode potentials seemed to have met with some success in reducing general corrosion of the tubes. One company simply placed blocks of zinc in the water box of the condenser and grounded the zinc to the condenser shell. The natural electrolytic tension of the zinc in salt water was sufficient to produce a noticeable potential against the condenser tubes. A more elaborate system suspends a number of cast iron

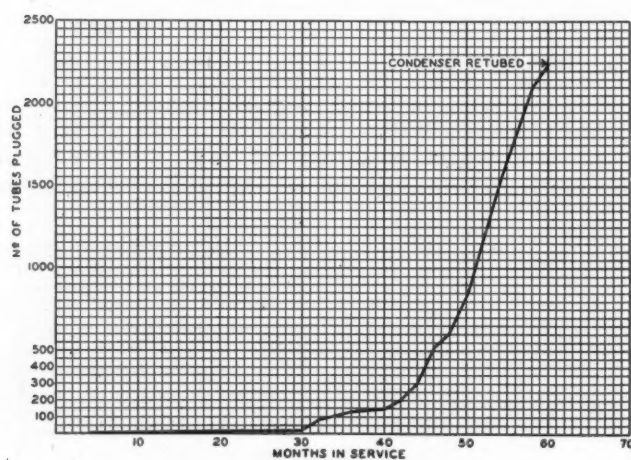


Fig. 5—Typical life curve of condenser tubes using East River water

electrodes, and a current density of several d.c. amperes per thousand sq. ft. of condenser surface is maintained positive to the tube sheet. Tube failures have been less on condensers so equipped than on other condensers at the same plant. Chlorine has been used to treat circulating water when the latter is contaminated with refuse which was causing slimy growths on the tubes. An aqueous solution of chlorine gas is admitted to the circulating water for a short interval once each hour. The concentration of the chlorine is sufficient to kill algae growths on the condenser tubes and cleaner condensers have been obtained. Longer life may be expected from tubes which do not have to suffer from repeated cleanings to remove deposits on tubes. Increasing the life of

tubes is one way of postponing troubles from condenser leakage.

Salt water condenser leakage introduces large and varying amounts of dissolved solids into the boilers complicating the boiler water conditioning problems already adversely affected by modern operating conditions. The remedy lies in detecting salt water condenser leakage by chemical and electrical means and extending the life of tubes and packing along the lines suggested by recent investigations.

Bibliography

1. Digby, *The Electrician* (London) Vol. 65, p. 646, (1910)
2. "Simplified Chemical Method of Detecting Surface-Condenser Leakage" By W. E. Caldwell, *Power*, Vol. 54, No. 4, July 26, 1921; pp. 141-142.
3. "The Electrical Method of Detecting Surface Condenser Leakage" By W. E. Caldwell, *Power*, Vol. 54, No. 6, August 9, 1921; pp. 217-219.
4. "Measurement of Surface Condenser Leakage by Electrolytic-Conductivity Method" By E. A. Keeler, *Power*, Vol. 55, No. 4, January 24, 1922; pp. 126-128.
5. "Measuring Condenser Leakage with a Meggar" By H. E. Edwards, *Power*, Vol. 60, 1924; pp. 907-908.
6. "Electrolytic Method for Testing Condenser Leakage" By A. E. Grunert, *Electrical World*, Vol. 89, No. 26, June 25, 1927; pp. 1384-1385.
7. "Conductivity Methods of Measuring Condenser Leakage" By H. C. Parker and W. N. Greer, *Power*, September 27, 1927; pp. 476-481.
8. "Electrolytic Prevention of Condenser Tube Corrosion" By F. G. Philo, *J. Am. Water Works Association* 20, 505, 34 (1928).
9. "Regulating Your Boiler Blowdown by Tests" By A. H. Moody, *Power Plant Engineering*, August 15, 1929; p. 912.
10. "Development of a High Pressure System for Boiler Water Conditioning" By A. A. Markson, *Combustion*, Vol. I, No. 10, April, 1930, pp. 27-30.
11. "Development of a High Pressure System for Boiler Water Conditioning" By R. E. Hall, *Combustion*, Vol. I, No. 11, May, 1930, pp. 45-46
12. American Society for Testing Materials Standards 1924. Standard Specifications for Seamless Admiralty Condenser Tubes. B 44-24.
13. "Electrical-Conductance Measurements of Water and Steam" By M. Hecht and D. S. McKinney. Preprint. Detroit Meeting A.S.M.E., June 9-12, 1930.

High and Net Heat Values of Fuels

By HENRY KREISINGER

Combustion Engineering Corporation, New York

European and American practice differs with respect to the heat value of fuel used in calculating boiler and furnace efficiencies. This has frequently led to unfair comparisons of the results obtained under practically the same conditions of fuel, equipment, operation, etc. It now appears quite probable that practice in this respect will be made uniform both here and abroad in the near future. Mr. Kreisinger explains the precise difference in these values, presents a table of comparative efficiencies and offers a simple formula for the conversion of efficiencies calculated on the low or net basis into efficiencies calculated on the high or gross basis.

THE statement is made at times that the boiled efficiencies obtained in Europe are very high and in some cases higher than those obtained in the United States with similar fuels and similar fuel burning equipment. It may be implied that these higher efficiencies obtained in European practice are the result of greater skill in burning the fuel. However, such in general is not the case. The best practice in burning fuel in the United States is equal to or, if anything, better than the best practice in Europe. It may be said also that the average American practice of burning fuels is better than the average European practice.

Most of the notably high efficiencies that are reported from Europe are due to the method of calculating the efficiencies rather than to greater skill in burning the fuel. In the United States, boiler efficiencies are figured on the basis of the gross, or, the high heat value of the fuel, whereas in Europe the results are calculated with the net or low heat value of the fuel. The difference between the two heat values depends on the hydrogen content of the fuel as burned. The higher the hydrogen content, the greater this difference. When hydrogen burns in a boiler furnace or in a standard bomb calorimeter, the product of combustion is steam. In the steam calorimeter, the products of combustion are cooled to within about 3 deg. of the initial temperature, the steam is condensed, and the latent heat of the condensed steam is a part of the heat value of the fuel as determined by the calorimeter. In the steam generating unit on the other hand, the temperature of the products of combustion are never cooled to low enough temperatures to condense the steam formed by the combustion of the fuel. In fact, every precaution is taken to prevent any condensation of the steam because the condensation would cause corrosion of the surface on which the

condensation took place, and soot and dust would adhere to the wetted surfaces, accumulate, and clog the gas passages. Inasmuch as in the process of steam generation it is not practical to make use of the latent heat of the water vapor produced by the combustion of the fuel, this latent heat should not be charged against the steam generating unit. Therefore, it is the practice in Europe to deduct the heat that would be released by the condensation of the water vapor and bringing the liquid to the temperature of the calorimeter from the heat value as determined by the calorimeter. The amount of heat so deducted is equal to the weight of water vapor per pound of fuel multiplied by the latent heat of water vapor plus the heat of the condensed liquid above the temperature of the calorimeter. The weight of water vapor per pound of fuel is obtained by multiplying the weight of the hydrogen content in the fuel as fired by nine. That is, if the hydrogen in the fuel as fired is 5 per cent, the weight of the water vapor formed in the process of combustion is .05 times 9 which equals to .45 pounds.

The latent heat released by the condensation is not so easy to ascertain because the condensation does not all take place at one temperature. With high hydrogen fuels, condensation may begin at a temperature as high as 130 deg. fahr. and it continues until the product of combustion has been cooled down to the initial temperature of the calorimeter. With fuels low in hydrogen contents, the condensation may not begin until a temperature below 100 deg. fahr. has been reached. The latent heat of water vapor increases as the temperature, at which condensation takes place, drops. Thus, the latent heat of water vapor condensed at 130 deg. fahr. is 1019 B.t.u. and at 80 deg. fahr. 1047 B.t.u. This variation of latent heat of water vapor with temperatures is shown by the upper curve of Fig. 1. However, water condensed at 130 deg. fahr. contains more heat than water vapor condensed at 80 deg. fahr. because part of the heat content in the liquid is also released after condensation when the liquid is cooled in the calorimeter to the initial temperature which is generally about 75 deg. fahr.

The lower latent heat of water vapor, condensed at higher temperatures, is further compensated by the fact that a greater weight of the vapor is condensed from a saturated mixture at higher temperature than is condensed for the same temperature drop from a

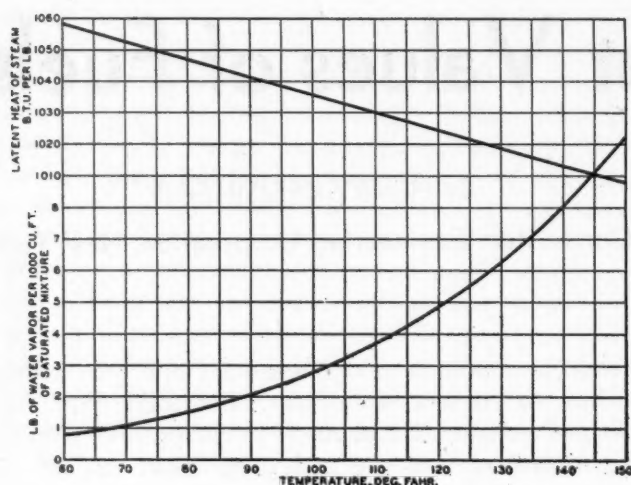


Fig. 1—Upper curve—Variation of latent heat of water vapor with the temperature at which condensation takes place. Lower curve—Weight of water vapor per 1000 cubic feet of saturated mixture at various temperatures of the saturated mixture

mixture at lower temperature. This is shown in Fig. 1 by the lower curve which shows the weight of water vapor per thousand cubic feet of saturated mixture. Thus, at 130 deg. fahr. 1000 cu. ft. of saturated mixture holds 6.35 lb. of water vapor. At 110 deg. fahr. 1000 cu. ft. of the mixture holds only 3.75 lb. of water vapor. If the temperature of the saturated mixture drops from 130 deg. to 110 deg. 2.65 lb. of the water vapor is condensed. At 100 deg. fahr. a saturated mixture contains 2.85 lb. of water vapor and at 80 deg. fahr. 1.58 lb. Therefore, by cooling the mixture from 100 to 80 deg. fahr. only 1.27 lb. of the vapor is condensed, which is less than one-half of the vapor condensed by the 20 deg. temperature drop from 130 degrees. It is, therefore, somewhat of a question what heat value should be used for the heat released by the condensation of the water vapor and cooling the liquid to the original temperature of the calorimeter. With natural gas as

fuel, the condensation of the vapor in the products of combustion starts at about 130 deg. fahr. With anthracite and coke, the condensation may start considerably below 100 deg. fahr. Apparently, no matter what value is assumed, it will not apply to all fuels with the same accuracy, and, therefore, a compromise must be made.

The American Society of Testing Materials recommends the value of 1040 B.t.u. whereas the Institute of Civil Engineers recommends the value 1055 B.t.u. On the European continent, where the net calorific value is in constant use, 600 calories per gram or 1080 B.t.u. per pound is used as a convenient value.

Table I shows the effect on the computed net calorific value and resulting boiler efficiency based on the net calorific value, when the lowest value of 1040 B.t.u. is used in the computation, and also the highest value of 1080 B.t.u. is used. In this Table are included fuels having different percentages of hydrogen. The values of column 4, which gives the weight of water vapor per pound of fuel formed by the combustion of fuel, are obtained by multiplying the percentage of hydrogen given in column 2 by 9 and dividing by 100. Columns 5 and 6 give the heat released by the condensation of the water vapor per pound of fuel and cooling the liquid to the calorimeter temperature. Column 5 is obtained by multiplying the values in column 4 by 1040 and column 6 by multiplying column 4 by 1080. Columns 7 and 8 indicate the net or low heat value of the fuels. These columns are obtained by subtracting respectively the values in columns 5 and 6 from the values in column 3. Column 9 gives an assumed efficiency of 80 per cent based on the high heat value of the fuel. Columns 10 and 11 give the efficiencies that would be obtained if the two net heat values given in columns 7 and 8 were used in computation. The difference between the values in columns 10 and

(Continued on page 47)

TABLE I

COMPARISON OF HIGH AND LOW HEAT VALUES OF VARIOUS FUELS AND THE EFFICIENCY OF STEAM GENERATION BASED ON HIGH AND LOW HEAT VALUES FOR FUELS WITH VARIOUS HYDROGEN CONTENTS AS FIRED

FUELS	Hydrogen in fuel per cent by wt.	High heat value —B.t.u.	Weight of water vapor formed by combustion —lb.	Heat released by condensation and cooling water vapor to calorimeter temp. —B.t.u.		Net or low heat value of fuels —B.t.u.		Assumed efficiency based on high heat value —per cent	Computed efficiency based on low or net heat value —per cent	
				5 1040 B.t.u.	6 1080 B.t.u.	7 1040 B.t.u.	8 1080 B.t.u.		10 1040 B.t.u.	11 1080 B.t.u.
West Virginia coal...	4.87	14,276	.438	456	473	13,820	13,803	80	82.6	82.7
Pennsylvania coal...	5.13	13,775	.462	480	499	13,295	13,276	80	82.9	83.0
Illinois coal.....	5.63	10,510	.507	527	547	9,983	9,963	80	84.1	84.3
Colorado black lignite	6.02	8,426	.542	563	585	7,863	7,841	80	85.7	85.9
Texas lignite.....	6.93	7,056	.6237	648	673	6,408	6,383	80	88.1	88.4
Mexican fuel oil.....	11.60	18,400	1.044	1086	1127	17,314	17,273	80	85.0	85.3
Pennsylvania fuel oil.	13.53	18,669	1.218	1266	1315	17,403	17,354	80	85.8	86.1
Arkansas natural gas.	24.6	23,800	2.214	2304	2392	21,496	21,408	80	88.6	88.9
West Virginia natural gas.....	23.2	23,400	2.088	2170	2255	21,230	21,145	80	88.2	88.5

The Pressure - Volume - Temperature Relation of Gases*

By WM. L. DE BAUFRE
International Combustion
Engineering Corporation
NEW YORK

This is the seventh article in the series by Mr. DeBaufre and the second on the subject of gases. As the author points out, the generally followed practice of using the pressure-volume-temperature relation of a perfect gas in problems involving real gases results in some degree of error, the amount depending upon the pressure and temperature of the gas. This practice, however, is sufficiently accurate for average purposes within reasonable limitations of temperature and pressure. The data for various gases contained in the Bureau of Standards publications referred to in the article may be used where more accurate information is needed. The next article in this series will deal with the thermal changes in gases and the expansion and compression of gases.

ENGINEERS generally apply the pressure-volume-temperature relation of a perfect gas in problems involving real gases without questioning whether any error is involved in so doing. As a matter of fact, real gases deviate from the equation of state for a perfect gas and the amount of deviation depends upon the pressure and the temperature of the gas. To more nearly represent the pressure-volume-temperature relation of real gases, many modifications have been proposed in the perfect gas relation. Such modified equations of state may be used to calculate various thermal data of real gases as well as to calculate the pressure, the volume or the temperature of the gas when the other two quantities are known.

Equation of State of a Perfect Gas

The equation of state of a perfect gas,

$$p v = R T,$$

was derived, as explained in a previous article, by combining the laws of Boyle and of Gay Lussac. When Boyle experimented on the "spring of air" in the latter half of the 17th century and concluded that the product of the pressure and volume of a given mass of air is constant at a given temperature, no temperature scale had yet been invented and but crude means were available for the measurement of the pressure and the volume of gases. As late as 1823,

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however, a French scientific commission appointed to secure data on steam, concluded that Boyle's law was strictly true for air up to a pressure of 27 atmospheres and probably to a considerably higher limit. The experiments upon which Gay Lussac's law was based for the effect of temperature change on the pressure or volume of a mass of gas, were made about the conclusion of the 18th century after temperature scales had been adopted but before definite standards had been developed for temperature measurements so that such measurements were somewhat crude. It was the careful work of Regnault on the compressibility of gases about the middle of the 19th century which showed that no gas exactly obeys Boyle's law or Gay Lussac's law.

The combination of Boyle's and Gay Lussac's laws, however, is a very convenient relation for determining say the volume of a given mass of air at any pressure and temperature when the volume is known at some other pressure and temperature. Thus, if we take the specific volume of air to be 12.39 cu. ft. per lb. at 32 fahr. and under normal atmospheric pressure, then the specific volume at 212 fahr. and under 10 atmospheres gage pressure may

be found by substituting in $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

$$\text{That is, } \dots \frac{1 \times 12.39}{32 + 459.6} = \frac{11 \times v_2}{212 + 459.6}$$

$$\text{Or, } \dots v_2 = 12.39 \times \frac{1}{11} \times \frac{212 + 459.6}{32 + 459.6} \\ = 1.539 \text{ cu. ft. per lb.}$$

It may be noted that the final volume is obtained by multiplying the initial volume by the ratio of the absolute pressures and by the ratio of the absolute temperatures. It is possible to write down this final expression without first substituting in the algebraic relation representing the combination of the laws of Boyle and of Gay Lussac if it is remembered that the volume must decrease with increase in pressure and must increase with increase in temperature. Similarly, in a problem where a change in pressure is produced by variations in volume and temperature, the final pressure may be found by multiplying the initial pressure by the ratio of volumes and by the ratio of pressures such that an increase in volume will lower the pressure and an increase in temperature will raise the pressure.

By calculating the specific volumes of air under various pressures at several different temperatures in

a manner similar to that used in the above example, it is possible to plot for each temperature a curve showing the corresponding values of pressure and volume as in Fig. 1. These isothermals for air con-

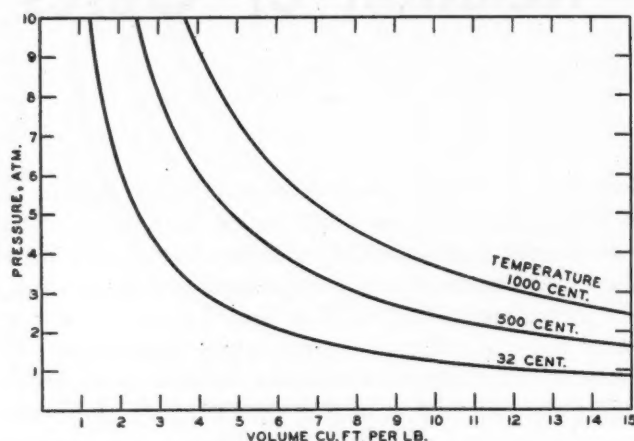


Fig. 1—Isothermals for air considered as a perfect gas

sidered as a perfect gas are rectangular hyperbolas, the product of the pressure and volume being constant at each temperature.

Deviations of Real Gases from the Relation of a Perfect Gas

For real gases, the product of the pressure and volume is not constant at a given temperature, as first shown by the experiments of Regnault and more fully investigated later by Andrews in 1863, by Amagat beginning in 1878, by Witkowski in 1891 and by others. The variations for atmospheric air are given by the curves of Fig. 2 where $273.1 \text{ pv}/T$ for different temperatures is plotted versus the pressure in atmospheres. The volume v is that of a mass of air which would have a volume of unity at 20 cent. under one atmosphere pressure. At 100 cent. and higher temperatures, the product of the pressure and volume continuously increases as the pressure increases. Below 100 cent., the product first decreases to a minimum value and then increases as the pressure increases. Other gases show the same phenomenon, as illustrated for oxygen in Fig. 3. Curves such as those of Fig. 2 and Fig. 3 may be used to obtain the volumes of air and of oxygen respectively at any pressure and temperature from the perfect gas relation $p_1 v_1/T_1 = p_2 v_2/T_2$. In order to determine the gas density at any temperature and pressure, its density at 20 cent. under one atmosphere must be known or the constant R must be available, preferably at zero pressure.

The constant R is determined for zero pressure because, as shown by Berthelot in 1904, all gases approach the perfect gaseous condition as a limit when the pressure is reduced to a very small value. The same value of R applies to all gases if a mass of each gas is considered equal to its molecular weight and known as one mole of the substance.

This is so because the densities of gases are approximately proportional to their molecular weights as discovered by Avogadro who stated in 1811 that at the same pressure and temperature equal volumes of all gases contain the same number of molecule. As the pressure is reduced, the proportionality becomes more nearly exact between densities and molecular weights of different gases.

It has been proposed by Henning to utilize the density of oxygen as the basis for the calculation of the "gas constant" R because the atomic weight of oxygen is taken as a basis for determining the atomic weights of other elements from their combining proportions with oxygen or from their relative gaseous densities. The density of oxygen at the temperature of melting ice and under normal atmospheric pressure is 1.4290 grams per liter. Dividing this into the molecular weight of 32 grams, we find the volume of one gram-mole of oxygen under one atmosphere at 0 centigrade to be 22.393 liters; consequently, $pv = 1 \times 22.393$ liter-atmospheres per gram-mole at zero centigrade and under one atmosphere pressure. At zero pressure, this product has been found by extrapolation of measurements at very low pressures to be 1.00094 times the value at one atmosphere, or 22.414 liter-atmospheres. Sub-

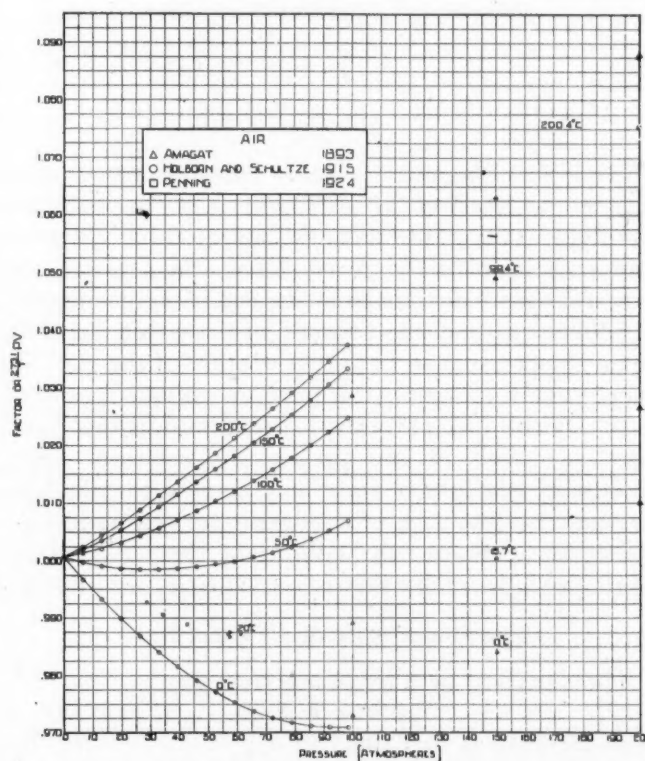


Fig. 2—Compressibility factors for air, from U. S. Bureau of Standards Circular No. 279

stituting in $pv = RT$ and taking $T = 273.1$ degrees Kelvin, we find $R = 0.08207$ liter-atmospheres per deg. cent. per gram-mole. The values adopted for the International Critical Tables are $R = 0.08206$ liter-atmospheres per deg. cent. per gram-mole and $v = 22.4115$ liters per gram-mole of gas at zero centi-

grade and one atmosphere pressure. The corresponding values for pressure measured in lb. per sq. ft., volume in cu. ft., mass in lb. and temperature in

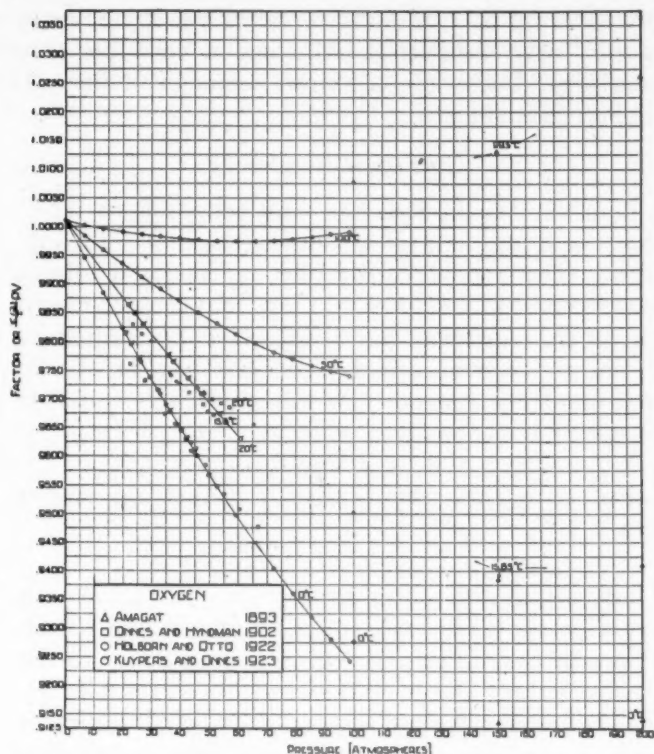


Fig. 3—Compressibility factors for oxygen, from U. S. Bureau of Standards Circular No. 279

fahr. absolute, are $R=1545.5$ ft.-lb. per deg. fahr. per lb.-mole and $v=359.0$ cu. ft. per lb.-mole of gas at 32 fahr. and one atmosphere pressure.

Oxygen gas is sold compressed in cylinders to pressures around 2000 lb. per sq. in., the standard cylinder to hold 200 cu. ft. of "free oxygen" having a volume of 1.528 cu. ft. If oxygen were a perfect gas, the volume of "free oxygen" at 20 cent. in a "200 cu. ft. cylinder" under 1500 lb. gage pressure and at 50 cent. would be obtained from

$$\frac{1 \times v}{273.1 + 20} = \frac{\left(\frac{1500}{14.696} + 1\right) \times 1.528}{273.1 + 50} = \frac{103.1 \times 1.528}{323.1}$$

Whence, $v=141.5$ cu. ft. of free oxygen. However, since oxygen is not a perfect gas, a factor of 0.973 must be used with a pressure of 103 atmospheres and a temperature of 50 cent. as shown by Fig. 3, the factor for atmospheric pressure and 20 cent being unity. Then,

$$\frac{1 \times v}{293.1} = \frac{103.1 \times 1.528}{0.973 \times 323.1}$$

Whence, $v=145.4$ cu. ft. of free oxygen. This value may be checked by Fig. 4 which gives the volume of oxygen measured at one atmosphere and 68 fahr. (20 cent.) in the standard "200 cu. ft. cylinder" at various pressures and temperatures.

To find the mass of oxygen in the cylinder, we can use the gas constant $R=1545.5$ ft.-lb. per degree fahr. per lb.-mole. At 20 cent. (68 fahr.) and under

one atmosphere pressure, the specific volume of the oxygen is

$$v = \frac{RT}{p} = \frac{1545.5 \times (459.6 + 68)}{14.696 \times 144} = \frac{385.35 \text{ cu. ft. per lb.-mole.}}{14.696 \times 144}$$

Or, $385.35/32=12.04$ cu. ft. per lb. Hence, there are in the cylinder, $145.4/12.04=12.08$ lb. of oxygen.

Equations of State for Real Gases

Instead of using the equation of state for a perfect gas and applying corrections for deviations of real gases therefrom, a modified equation of state may be employed to calculate directly the pressure, volume or temperature of a real gas under specified conditions. The first modification in the perfect gas equation of state was proposed by Rankine in 1854 to represent the data obtained by Regnault on the compressibility of carbon dioxide. Rankine's equation of state is

$$pv = RT - a/Tv \text{ or } p = \frac{RT}{v} - \frac{a}{Tv^2}$$

Joule and Thomson proposed in 1862 the form

$$pv = RT + ap/T^2$$

to represent the results of their throttling experiments on air and carbon dioxide.

The most often given example of an equation of state for real gases is the one proposed by Van der

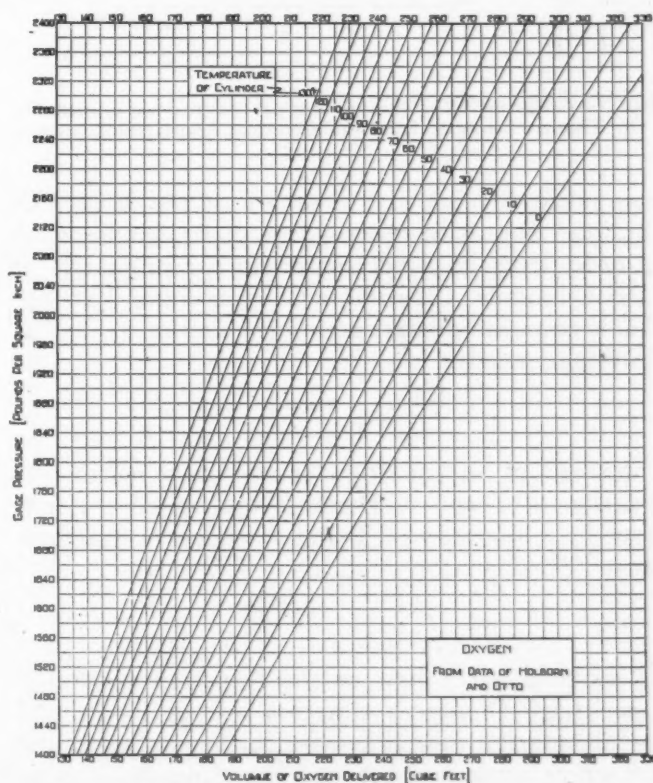


Fig. 4—Volume of oxygen (measured at 1 atm. and 68 fahr.) delivered from a cylinder the volume of which is 1.528 cu. ft., from U. S. Bureau of Standards Circular No. 279

Waals in 1873 in his essay on the continuity of the liquid and gaseous states of matter, namely,

$$(p + a/v^2)(v - b) = RT \text{ or } p = \frac{RT}{v - b} - \frac{a}{v^2}$$

This equation was based on theoretical considera-

tions—the constant b represents the deduction from the total volume v due to the volume of the molecules and the term a/v^2 represents the attraction between the molecules which must be resisted in addition to the external pressure p . The molecular attraction

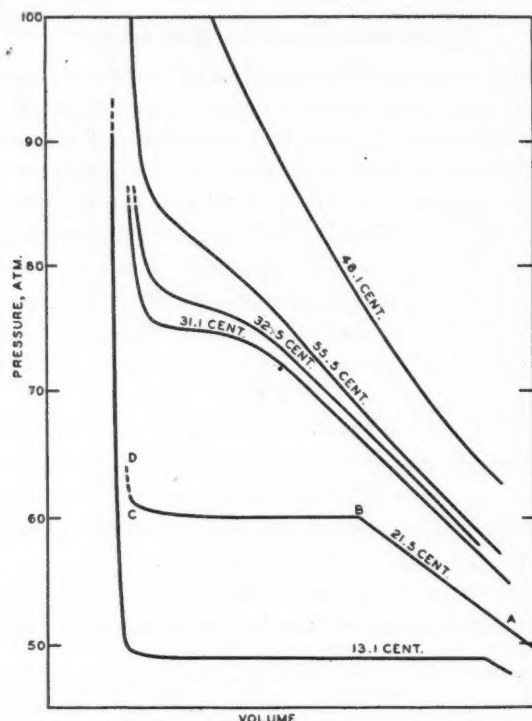


Fig. 5—Isotherms for carbon dioxide obtained experimentally by Thomas Andrews, from Philosophical Transactions, 1869

was taken to vary as the square of the density of the fluid but to be independent of its temperature. In order to more closely represent the properties of carbon dioxide, Clausius in 1881 modified Van der Waals equation of state to a form similar to that of Rankine, namely,

$$P = \frac{RT}{v-b} - \frac{a}{T(v+c)^2}$$

Instead of subtracting a second term which is a function of T and v , Dieterici multiplied the first term by a function of T and v which is less than unity. His equation of state is

$$P = \frac{RT}{(v-b)} e^{-c/RTv}$$

in which e is the base of the Naperian system of logarithms. Dieterici's equation was derived under the assumption that it is only at the surface of the gas where attraction between the molecules acts to reduce the effective pressure by pulling the molecules toward the interior of the gas. A revised form is,

$$P = \frac{RT}{v-b} - \frac{a}{T^{1.27}v}$$

Berthelot's equation was derived for use in molecular weight determinations based on the densities of gases and was originally intended to apply between 0 and one atmosphere only. It has the form

$$P = \frac{RT}{v-b} - \frac{a}{Tv^2}$$

Of the above equations, Berthelot's is preferred for pressures up to 5 or 6 atmospheres but is not satisfactory near the critical point nor at very low temperatures. Dieterici's equation is preferable for conditions near the critical point.

Corresponding States

Van der Waals equation was proposed to represent the liquid as well as the gaseous state of a substance. The critical temperature, pressure and volume discovered by Andrews in 1869, may be accounted for by this equation; and if these are represented by T_c , p_c and v_c respectively, then it may be shown that the three constants in Van der Waals equation of state have the values

$$a = 3p_c v_c^2, b = v_c/3 \text{ and } R = 8 p_c v_c/3 T_c$$

Substituting these three values, the equation reduces to

$$\frac{p}{p_c} = \frac{8 T/T_c}{3 v/v_c - 1} - \frac{3}{(v/v_c)^2}$$

Thus, all fluids conforming with Van der Waals equation of state have equal corresponding values of pressure, volume and temperature relative to the critical values and may therefore be represented by the same pressure-volume diagram with different scales to suit the different critical values of the various fluids. This is an approximate relation which is useful for finding the thermal properties of similar fluids from the thermal properties of one of them and is known as the law of corresponding states. The law of corresponding states, however, is not even

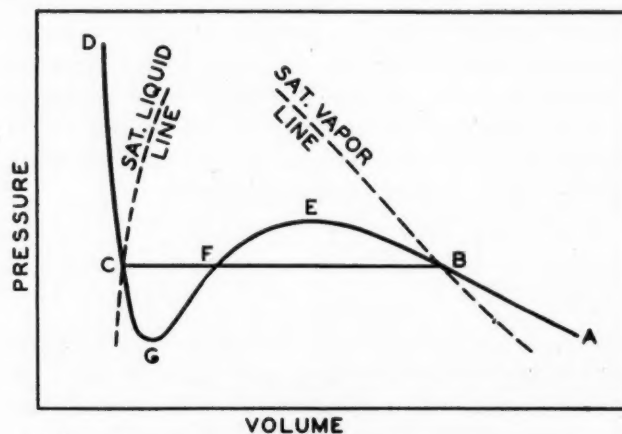


Fig. 6—Thomson theoretical isothermal for real gases below the critical temperature

approximately true for fluids of dissimilar compositions.

Isotherms for Real Gases

Isothermal pressure-volume curves for real gases deviate from rectangular hyperbolas at high pressures and at low temperatures. If the temperature is below the critical value, liquefaction of the gas occurs when the pressure is increased sufficiently. The isotherms for carbon dioxide, which has a

critical temperature of 31.1 cent., were first investigated by Thomas Andrews. The curves of Fig. 5 are taken from his paper On the Continuity of the Gaseous and Liquid States of Matter which was published in the Philosophical Transactions in 1869. For a temperature of 21.5 cent., the isothermal in the gaseous region is similar to that of a perfect

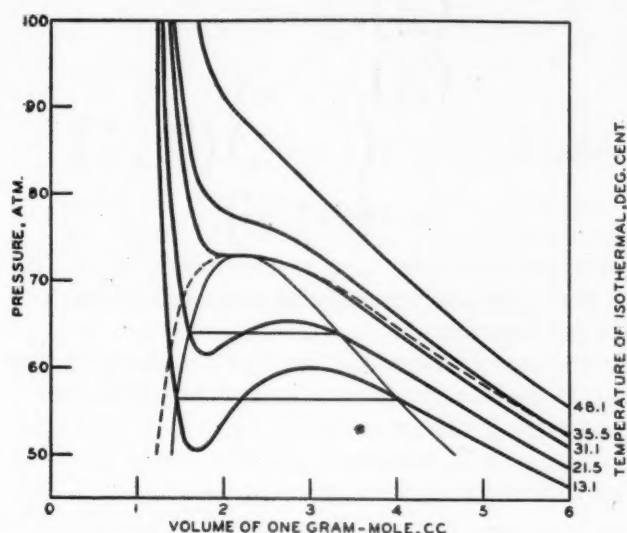


Fig. 7—Isotherms for carbon dioxide calculated by Van der Waals equation of state

gas, the volume decreasing as the pressure is raised from point A until the saturated vapor pressure is reached at point B. The vapor then begins to condense without further increase of pressure. At C the vapor is completely liquefied. Any further compression produces a very rapid rise in pressure to some point D. The isothermal for 31.1 cent. has no horizontal portion but a point of inflection only at the critical pressure and volume where the carbon dioxide changes from gas to liquid without a definite separation of the two states being noticeable. Above the critical temperature, the isotherms approach more closely those of a perfect gas as shown by the isotherms for 35.5 and 48.1 cent.

James Thomson suggested in 1871 that instead of discontinuities in the isotherms below the critical temperature, the liquid and vapor portions might be connected by a continuous curve such as BEFGC in Fig. 6. It has since been found possible to trace experimentally portions of this curve between points B and C. Thus, vapor has been compressed above point C in the absence of liquid or hygroscopic surfaces on which condensation could start. Expansion of liquid has been carried below point C by carefully freeing it of dissolved air so that no small bubbles existed to start vaporization.

The theoretical isotherms of James Thomson are represented qualitatively by Van der Waals equation of state proposed in 1873. Taking the form of this equation derived above for the temperature, pressure and volume in terms of the critical values, the isotherms of Fig. 7. have been calculated for

carbon dioxide, using $T_c = 304.2$ K., $p_c = 72.95$ atm. and $v_c = 2.15$ cc. per gram-mole from the International Critical Tables. Maxwell in 1875 showed from considerations based on the second law of thermodynamics which has not yet been discussed in these articles, that the horizontal lines joining the liquid and gaseous portions of the isotherms below the critical temperature should be so drawn as to cut off loops of equal area from the imaginary isotherms. By so doing, the dome-shaped curve passing through the extremities of these horizontal lines is obtained in Fig. 7 to inclose the region within which both the gaseous and liquid states exist together in equilibrium.

In Fig. 7 has also been drawn a dotted dome-shaped curve showing the specific volumes of the liquid and the saturated vapor given in the International Critical Tables for carbon dioxide. It will be noticed that the actual volumes of liquid and of saturated vapor differ greatly from the values obtained by applying Maxwells theorem to the isotherms of Van der Waals equation. An equation of state containing only three constants can not accurately represent the pressure-volume-temperature relation for most fluids. A greater number of constants is required or the equation must be applied to a small region only. As mentioned in a previous article, it is difficult to find an equation of state to represent the pressure-volume-temperature relation of steam with sufficient accuracy for practical purposes.

Compressibility Curves from Equations of State

Compressibility curves for oxygen at zero centigrade are given in Fig. 8 as calculated from the

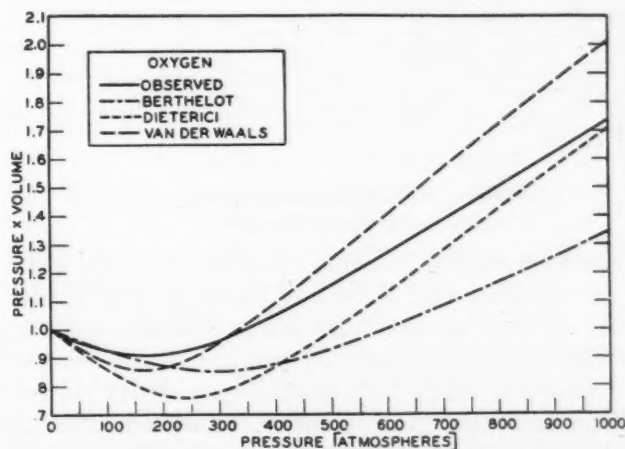


Fig. 8—Comparison of experimental data on the compressibility of oxygen at zero cent. with values calculated by the equations of Berthelot, of Dieterici and of Van der Waals, from U. S. Bureau of Standards Circular No. 279

equations of state of Van der Waals, of Dieterici and of Berthelot, for comparison with the experimentally determined curve. The value of the product p_v at zero pressure has been taken as unity. At this point the volume v is infinite.

For Van der Waals equation,

$$(p v)_{p=0} = \frac{R \cdot 273.1}{1 - \frac{b}{\infty}} - \frac{a}{\infty} = 1$$

$$\text{whence } R = \frac{1}{273.1}$$

Since for oxygen, $T_c = 154.3 \text{ K}$, and $p_c = 49.7 \text{ atm.}$, the constants in Van der Waals equation become

$a = 0.002710$ and $b = 0.001421$. Hence

$$p v = \frac{T}{273.1 \left(1 - \frac{0.001421}{v}\right)} - \frac{0.002710}{v}$$

For Dieterici's equation, the constants are

$$R = \frac{1}{273.1}$$

$$b = \frac{R T_c}{p_c e^2} = 0.001538$$

$$a = 4 b T_c^{1.27} = 3.700$$

$$\text{whence } p v = \frac{T}{273.1 \left(1 - \frac{0.001538}{v}\right)} e^{-3.7/T^{1.27} v}$$

For Berthelot's equation, the recommended empirical values of the constants are:

$$a = 16 p_c v_c^2 T_c / 3; b = v_c / 4; R = 32 p_c v_c / 9 T_c$$

Eliminating the critical volume v_c , we have $a = 27 R^2 T_c^3 / 64 p_c$. Substituting the values for oxygen, we obtain

$$a = 0.4181 \text{ and } b = 0.000800$$

Whence,

$$p v = \frac{T}{273.1 \left(1 - \frac{0.0008}{v}\right)} - \frac{0.4181}{T v}$$

By reference to Fig. 8, it is seen that none of these equations exactly fits the experimental data. From 0 to 200 atm., Berthelot's equation is closest; from 200 to 600 atm., Van der Waals equation is best; and for 600 to 1000 atm., Dieterici's equation is preferable.

Calculation of Differences between Specific Heats of Gases

Another use for an equation of state of real gases is to calculate the difference between the specific heats at constant pressure and at constant volume, for this difference is not independent of the pressure and temperature as for a perfect gas. Based on certain fundamental principles of thermodynamics which have not yet been discussed in these articles, it may be shown that for fluids in general,

$$c_p - c_v = A \cdot T \left(\frac{\partial p}{\partial T} \right)_v \left(\frac{\partial v}{\partial T} \right)_p$$

For the equation of state of a perfect gas,

$$\left(\frac{\partial p}{\partial T} \right)_v = \frac{R}{v}$$

$$\left(\frac{\partial v}{\partial T} \right)_p = \frac{R}{p}$$

$$\text{Therefore, } c_p - c_v = A \cdot T \times \frac{R}{v} \times \frac{R}{p} = A R$$

Substituting $A = 1/778.6 \text{ B.t.u. per ft.-lb.}$ and $R = 1545.5 \text{ ft.-lb. per deg. Fahr. per lb.-mole}$, we obtain $C_p - C_v = 1.985 \text{ B.t.u. per lb.-mole per deg. Fahr.}$ for a perfect gas.

For the Berthelot equation of state,

$$\left(\frac{\partial p}{\partial T} \right)_v = \frac{p}{T} + \frac{2a}{T^2 v^2}$$

$$\left(\frac{\partial v}{\partial T} \right)_p = \frac{R}{p} + \frac{2a}{R T^2}$$

$$\text{Therefore, } c_p - c_v = A \cdot T \left(\frac{p}{T} + \frac{2a}{T^2 v^2} \right) \left(\frac{R}{p} + \frac{2a}{R T^2} \right) = A R \left(1 + \frac{4a}{R^2 T^2} \right)$$

At low pressures and high temperatures, the difference in the specific heats of real gases approaches the value for a perfect gas.

Berthelot recommended for the constants in his equation of state (when used for low pressures only), the empirical values, $a = 16 p_c v_c^2 T_c / 3$; $b = v_c / 4$; $R = 32 p_c v_c / 9 T_c$; whence $a = 27 R^2 T_c^3 / 64 p_c$. The above difference then reduces to

$$c_p - c_v = A R \left(1 + \frac{27 p}{16 p_c} \frac{T_c^3}{T^2} \right)$$

Taking $T_c = 132.4 \text{ K}$. and $p_c = 37.2 \text{ atm.}$ for air from the International Critical Tables and substituting $A R = 1.985 \text{ cal. per gram-mole per deg. cent.}$, we obtain for $p = \text{one atmosphere}$ and $T = 273.1, 373.1$ and 773.1 cent. respectively:

Temperature, cent.	$c_p - c_v$ cal. per gm.-mole per deg. cent.
0	1.995
100	1.989
500	1.985

These values show that above the temperature of melting ice, the difference in the specific heats at constant pressure and at constant volume may be taken as constant for atmospheric air, as stated in the preceding article on the thermal properties of gases.

Calculation of Change in Internal Energy

By means of an equation of state for real gases, it is also possible to calculate the rate of change of the internal energy with change of volume at constant temperature, that is, the "Gay Lussac effect." This is accomplished by a general thermodynamic relation which will be derived in a future article, namely,

$$\left(\frac{\partial u}{\partial v} \right)_T = A T \left(\frac{\partial p}{\partial T} \right)_v - A p$$

Applying this general relation to the equation of state of a perfect gas, we get

$$\left(\frac{\partial u}{\partial v} \right)_T = A T \frac{R}{v} - A p = 0$$

which is in accordance with Joule's law. Applying

(Continued on page 47)

Electric Boilers Improve Load Factor of European Generating Stations

By C. H. S. TUPHOLME, London

CENTRAL station engineers of Great Britain are engaged in an intensive campaign of load-building, and, in all parts of the country every effort is being made to increase the load on the central generating stations, particularly on new plants, now being put into operation.

One of the most interesting results of the drive to extend the use of electricity for heating purposes is the development of the electric boiler, which, designed to operate during the time when electricity charges are low, as at night, can heat water and store it for use during the day when the cost of current is again normal.

The electric boiler is primarily a Continental development where it has proved exceedingly valuable for raising steam and heating water in many industries, such as cellulose works, paper mills, dye works, bleaching works, spinning mills and chemical works, as well as in agricultural work, distilleries, dairies, laundries, disinfecting works, bath houses, schools, churches and hospitals.

According to the work for which they are installed and the time when current is available at preferential rates, electric boilers are constructed either for raising steam and heating water for immediate use, or for storing the steam and water until required. It is therefore necessary to differentiate between electric hot-water boilers, electric hot-water accumulators, electric steam boilers and electric steam accumulators.

In the course of development two systems of electric heating have been devised, the field of application of each being limited by the kind of current used and the load required.

Small electric steam and hot water boilers utilizing only a small amount of either direct or alternating current, and boilers for which only direct current is available, are made on the indirect resistance principle, that is, they are fitted with coil or strip resistances of high-grade, heat resisting material, mounted on insulators and inserted in heating tubes (Fig. 1). In order to provide means for regulating the load on such boilers to suit the momentary demand for steam or hot water, the heating tubes are coupled in groups and connected to the source of current through suitable switches and fuses. If electric resistances, such as are used for smaller steam and hot-water boilers,

Electric boilers are coming into extensive use in Europe. Up to the present, units have been installed for loads ranging from 10 to 6000 kw. and it is expected that units of considerably higher capacity will soon be available. The author describes the various types of electric boilers now in use and discusses their fields of application. This development is regarded as an important factor in load-building of public utilities and in effecting better load distribution by building up off-peak demands.

were adopted for larger plants, it would lead to many difficulties because of the many connections and contacts which would then be required; they are therefore unsuitable for such work.

For heavy loads, and in special cases even for loads of over 10 kw., particularly for voltages exceeding 500 volts, the plants most suitable are those built according to the electrode system, in which the water itself is utilized as resistance. This system can, however, be adopted only when alternating current is available, since direct current would decompose the water into hydrogen and oxygen, forming an explosive mixture. It was formerly thought that a similar gas mixture would be generated by an electrode system, even when connected to a source of alternating current and that consequently there would be danger of explosion. Tests with electrode systems have, however, shown that the quantity of hydrogen and oxygen formed at the electrodes is so slight that the oxygen formed combines at once with the iron parts, while the small quantity of hydrogen mixes with the steam. It should, however, be noted that the amount of hydrogen and oxygen formed at the electrodes is greater with low periodicities, for example with alternating current of 15 cycles, than with high ones, such as currents of 50 cycles, and that the amount of hydrogen and oxygen formed is also greater at high voltages than at low ones. Careful tests, carried out in the presence of well-known physicists, have shown that the quantity of gas formed, even with alternating current of 15 cycles, is so slight that there is no danger to be feared from explosion.

Nowadays alternating current is available practically everywhere and it can be introduced directly to electric steam and hot-water boilers at voltages up to 16,000 without any need of transforming down to lower voltages. Transformers, which would greatly

increase the cost of the installation, are therefore eliminated and the overall efficiency of a plant with the electrode system is higher than one fitted with metallic heating-resistances.

Up to the present, electric steam and hot-water boilers have been installed for loads of 10 to 6000 kw. and it is possible that boiler units of much greater capacity, taking loads of over 6000 kw. will soon be built.

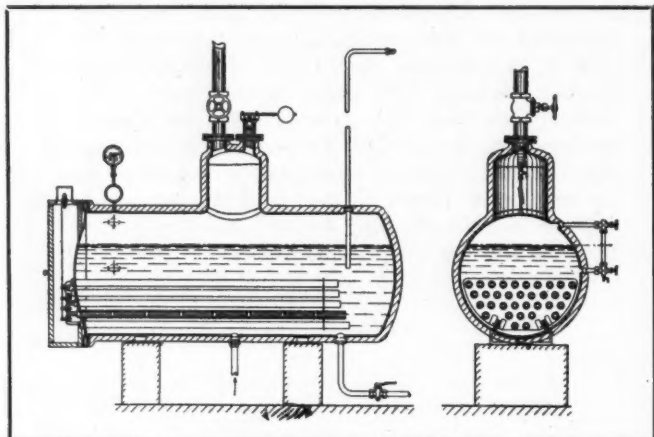


Fig. 1—Small electric boiler using indirect resistance principle

As mentioned above, the water in the electrode boilers serves as the resistance for converting the electric energy into heat energy. The electric resistance of the water depends on its chemical composition and on the temperature. Water with a large quantity of salts dissolved in it is a much better conductor of electricity than soft water.

In designing an electrode system, the conductivity of the water does not play such an important part as might easily be imagined, since it can be kept at a practically constant and suitable figure by the addition of chemicals and by blowing-down as frequently as required. It is, however, important to note that the resistance should be chosen as high as possible, since the distance between the electrodes and also their cross-section can then be kept large, and this means small specific loads per unit area and per unit volume. In general, electric boilers work with specific resistances varying between 500 and 1000 ohms per cu. cm. There are electric boilers which are designed for considerably lower specific resistances. Such boilers are much smaller in size, but the specific load is greater and the reliability of working is consequently enormously reduced. It has often been found necessary to limit the load on such boilers to a point much below the originally rated figure, in order to avoid having to change the electrodes too frequently, as they are quickly eaten away under the high specific load they have to carry. Because the electrode system in these boilers was designed for a high specific resistance, the boilers can be heavily overloaded by altering the specific resistance without materially increasing the wear of material. There are for example boilers in service, which are loaded continuously to 350 per cent of the rated figure.

It has been found that, when using high voltages, there is for each voltage a certain minimum load below which it should not be permissible to go otherwise the safety at normal load would be affected. For this reason boilers are seldom installed for loads lower than 50 kw. at 3000 volts, 100 kw. at 5000 volts, 200 kw. at 8000 volts and 500 kw. for voltages higher than 10,000 volts three phase.

Other types of electric boilers are used in which the electrodes are not completely immersed in the water. In such boilers, at voltages higher than about 1000 volts, sparking begins to make its appearance at the surface of the water, thus causing the load on the boiler to fluctuate and the electrodes to wear down much more quickly than they would otherwise do. For this reason, the electrodes in the electric boiler most widely adopted are wholly immersed in the water. Current is conducted to them by the current-inlet piece in the top of the boiler, covered by an insulating tube.

Electrode systems have been developed for low voltage and high voltage. A system of electrodes for use with a low-voltage boiler is shown in Fig. 2 (only one phase is indicated). The electrode system consists essentially of the current-inlet pieces, the fixed electrodes, the movable counter-electrodes and the regulating gear. The position in which the counter-electrodes are shown in the sketch corresponds to maximum load. The current flows from the electrode

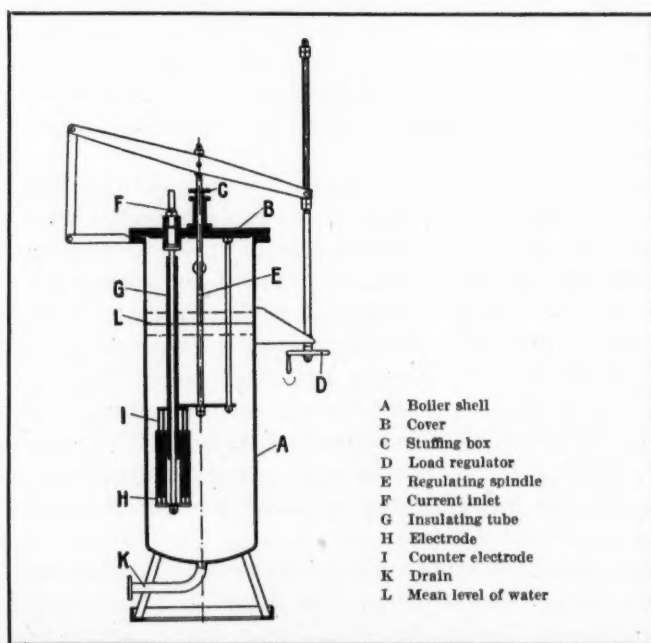


Fig. 2—System of electrodes for low voltage boiler

cylinders H to the counter-electrode cylinders I. The area of section through which the current flows is comparatively large, and since the distance the current has to traverse can be kept very short with low voltages, large loads can be carried by these systems within a small volume. At minimum load the counter-electrodes are raised completely out of the electrode cylinders, the cross-section traversed by the current is

small and the distance the current has to flow can be made large by raising the counter-electrode cylinders, so that the minimum load can be kept small. Electrode systems have been built on this principle for loads up to 2500 kw. for working on low voltages and the results obtained from these boilers have proved highly satisfactory.

The fundamental idea of the high-voltage system (Fig. 3) consists in an electrode C, completely immersed in the water, being surrounded by a movable insulating tube D, the so-called evaporating tube. At any position of the regulating device the evaporat-

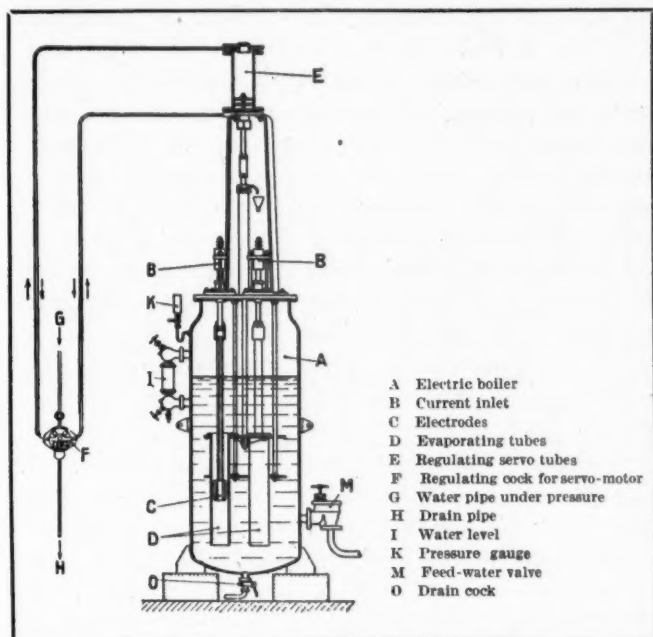


Fig. 3—High voltage system

ing tube is completely immersed in the water. The position shown in the sketch in Fig. 3 corresponds to the minimum load of the electrode system. Current flows through the water in the lower and upper parts of the electrode C in the evaporating tube to the grounded parts in the boiler. The water in the evaporating tube is thereby heated and consequently rises. The colder water flows in below to take its place. By raising the evaporating tube, the path of the current from the lower edge of the electrode to the lower edge of the evaporating tube is shortened, the electric resistance is decreased, and consequently the load is increased. The load reaches the maximum when the electrodes are still about 2 in. within the evaporating tube.

With this arrangement, only relatively small loads, up to about 150 kw. per electrode, can be carried, and only for voltages up to about 8000; at higher voltages the steam bubbles formed round the electrodes are no longer regularly removed from the electrodes by the natural upward flow of the water. The steam bubbles adhering to the electrodes act as insulators, causing a temporary decrease in the effective electrode surface and consequently also fluctuations in the load. This drawback in the case of high loads, is overcome by

washing the bubbles off by means of a system of forced circulation. This is effected by a pump which keeps the water in the boiler circulating through the electrodes.

In order to maintain a steady, uniform load in boilers carrying high loads at high voltages, the electrode systems have for some years been designed

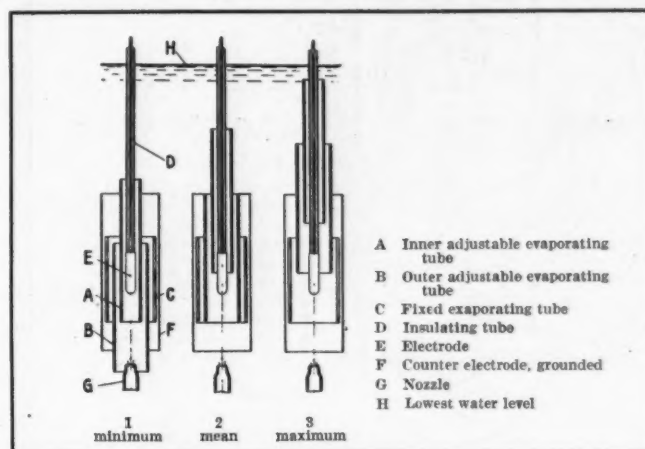


Fig. 4—Design of electrodes for boilers carrying high loads at high voltages

as shown diagrammatically in Fig. 4 (where only one phase is indicated). Sketch 1 in Fig. 4 shows the position of the evaporating tube at minimum load. The electric current flows out from the electrode upwards and downwards through the water column in the evaporating tube 1 to the grounded parts of the boiler or to the counter-electrode. In order to increase the loading, both the evaporating tubes 1 and 2 are raised by a regulating gear, so that, at average load, they approach the position shown in Sketch 2, Fig. 4. Sketch 3, Fig. 4 corresponds to the position taking maximum load. The greater part of the electric energy is always converted into heat in the space below the electrode in the various positions 1, 2 and 3, and the various sketches show very clearly that small quantities of water take part in this conversion at low loads and large quantities of water at high loads. The mean specific load per unit of volume with this electrode system, therefore remains approximately constant for all loads. By means of the telescopic movement of the evaporating tubes, a steadily rising regulation curve is obtained, so that the increase in load is always nearly proportional to the height the tube is raised.

The electrode system described has an advantage over other systems, in that it can be made with smooth, cylindrical insulating tubes, whereas insulating pieces of varied shapes are required in the systems of other designs. The stresses caused by the change of temperature are much smaller in the material of smooth tubes than in complicated parts, especially when there are several changes in the cross-section of the material. Electrode systems have been made according to the arrangement shown in Fig. 4 for loads up to 6000 kw. and for voltages up to 16,000 volts three-phase.

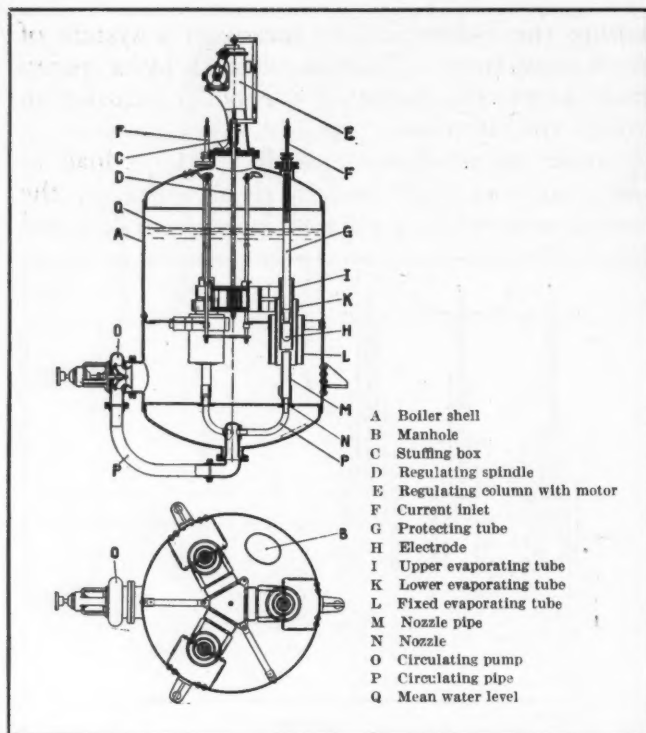


Fig. 5—Section through 6,000 kw. boiler

Fig. 5 shows a section through an electric boiler for a load of 6000 kw. Here, a telescopic arrangement is adopted for adjusting the evaporating tubes. The evaporating tubes I and K are hung on a three-armed piece, which itself is supported on a spindle D (the regulating spindle), which passes out of the boiler through the stuffing box C. Stops fitted in the boiler limit the movement of the spindle and determine

the maximum and minimum loads on the boiler.

The spindle can be adjusted in any of the four following ways: by hand, by means of a cross piece (as shown diagrammatically in Fig. 2, by worm gear driven by an electric motor, worked by push buttons (as in the boiler shown in Fig. 5); by hydraulic pressure using a water-motor, operated by hand by a regulating valve (as in Fig. 3) or automatically, by means of a water-motor which is operated by apparatus controlled by the boiler pressure or by the momentary load on the boiler.

An electric boiler about 6 ft. in diameter and 10 ft. high, similar to the one shown in Fig. 5, has been supplied to the Building Department of the Municipality of Basle for the Friedmatt Nursing Home at Basle. The boiler is equipped with an electrode system for a maximum load of 2400 kw. on 6400 volt three-phase supply. The plant in the Friedmatt Nursing Home comprises the electric boiler with a pump for forced circulation of the water, a water-motor, the various automatic devices for regulating load, pressure and water level, an electrically driven feed pump, a feed water filter, electric switch gear and the steam piping to the three existing, large, coal fired boilers. The plant operates absolutely automatically either at constant pressure or at constant load.

As already mentioned, the electric resistance of the water depends on its composition. All water contains some salts which increase its conductivity. By the evaporation of the water in the boiler, the conductivity is continually increased owing to the salts remaining in the boiler, so that after a time it is

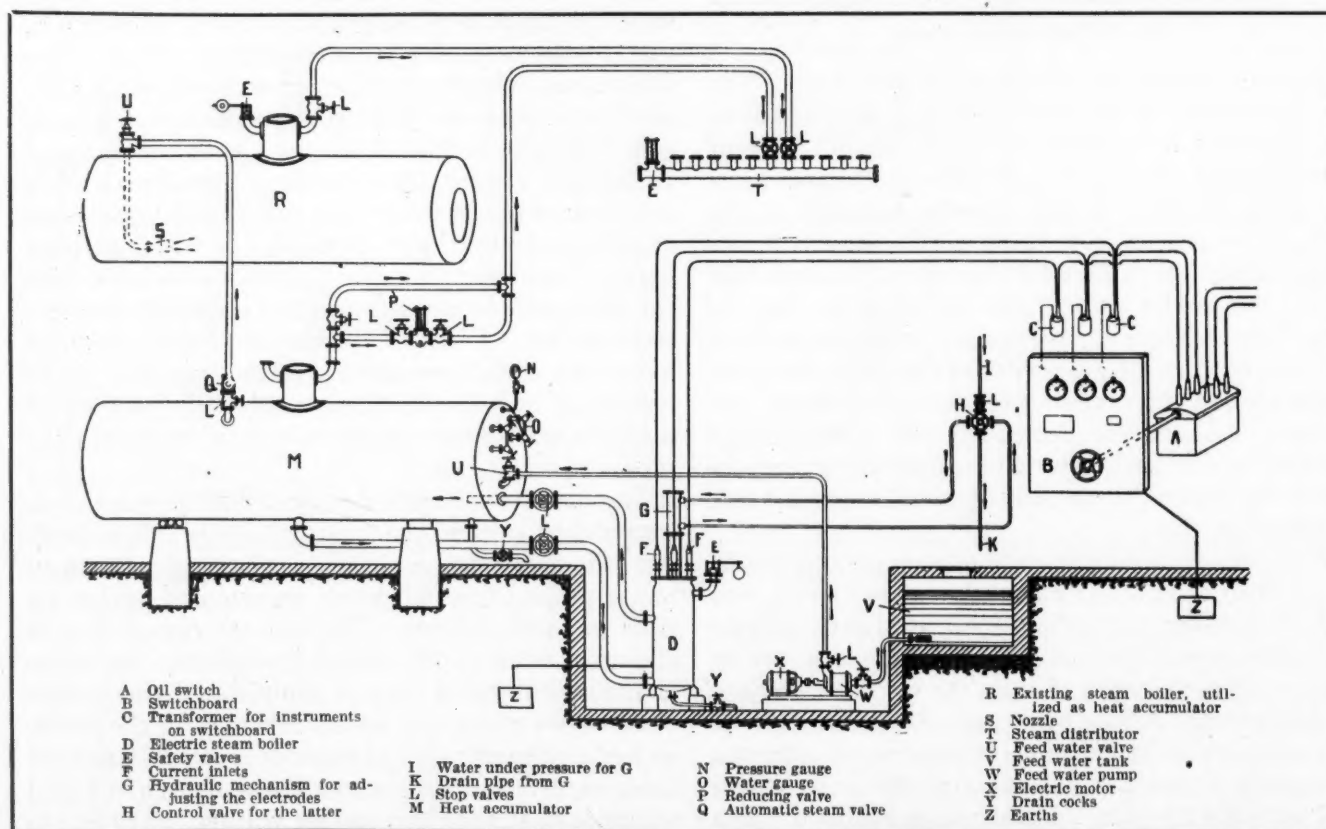


Fig. 6—Electric steam boiler plant with heat accumulator

not possible to run it at the minimum load. In boilers taking a low load, it is sufficient to blow down the boiler once a day in order to prevent the conductivity becoming too high. In large electric boilers it is necessary to blow down continuously; the water drawn off is then led through a heat exchanger in order to avoid heat losses.

The efficiency of an electric boiler supplying steam for direct use is very high, since the heat losses due to radiation are slight in consequence of the small surfaces exposed, and the losses in blowing down are not very great with normal feed water. If the steam is passed into an accumulator, the efficiency of the plant will to a large degree depend on the quality of the lagging.

Fig. 6 illustrates a case commonly occurring in practice, an electric steam boiler plant with a heat accumulator. By means of electric energy taken during the night, the water in the electric boiler D is heated to a temperature somewhat higher than that of the water in R and partly converted into steam. The mixture of steam and water passes through a pipe into the heat accumulator M and warms the contents. The steam formed here passes partly through a nozzle S into the coal-fired boiler R, which can also serve as a second heat accumulator. The rest of the steam raised in M is reduced to the pressure in R by means of the reducing valve P and passed to the distributor T and thence to the place where it is used. The steam forming in R also passes to the same distributor. The feed-water is introduced into M at U. H is the control valve for operating the hydraulic gear for adjusting the electrodes. This allows the load on the boiler to be regulated in accordance with the amount of steam required at the moment.

Electric boilers are also suitable for central heating and warm water supply. In such plants it has to be considered that the demand for heat fluctuates

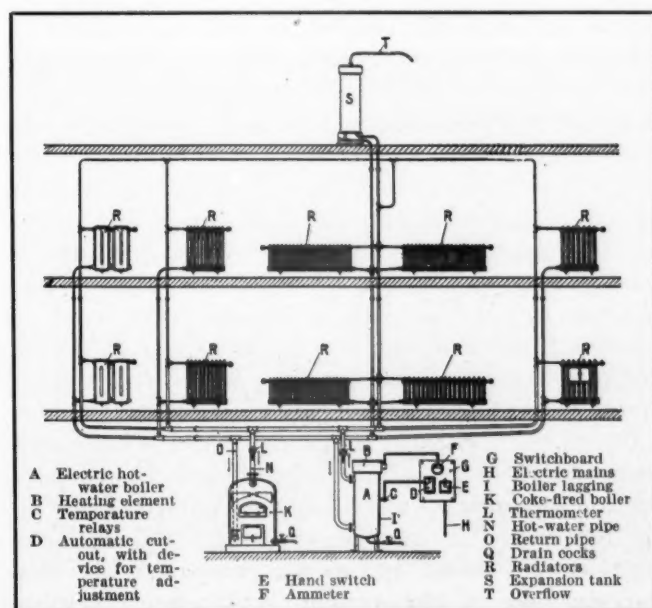


Fig. 7—Combined electric and fuel boiler for central heating

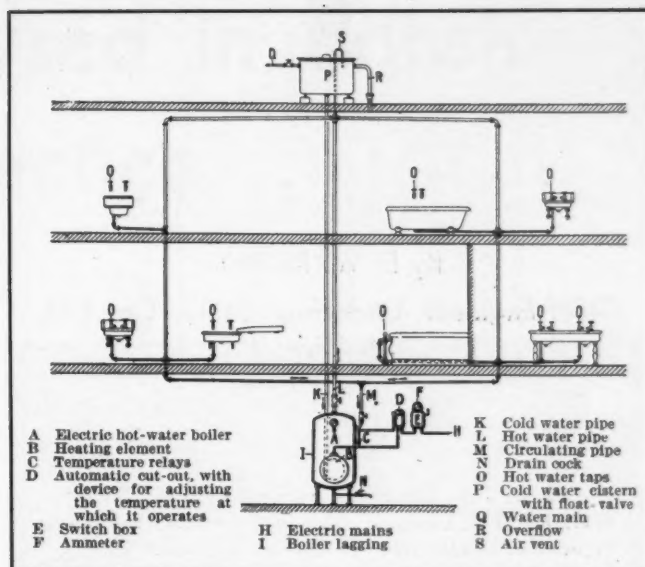


Fig. 8—Electric boiler for hot water heating

greatly, depending on the outside temperature. The most suitable and practical method of utilizing electric energy for economizing fuel in heating buildings, consists in operating an electric boiler in parallel with a coal-fired boiler. This auxiliary plant allows the entire heat requirements to be supplied by electric energy in Spring and Autumn, when the cold is not intense. During periods of severe cold, the coal-fired boiler can also be put into service, the extent to which it is used depending on the capability of the electricity works to supply electric energy. The coal-fired boiler also serves as a stand-by to take the whole load in case of total failure of the electric supply.

Figs. 7 and 8 show examples of the adoption of electric boilers in hot-water central heating and hot-water supply plant.

Several installations of these boilers are operating satisfactorily in London at the Regent Street Polytechnic, Artillery House, Westminster and at the Offices of the Commercial Union Assurance Co. in the financial quarter of London. These installations are supplied with high tension current at the rate of approximately 0.35 penny per kilowatt hour. In these buildings, the current is turned on at eight o'clock in the evening and the heat is stored for use during the day period, the size of the storage vessels being proportional to the day load. In the case of the Polytechnic the thermal storage content is about 28,000 gal. in three vessels each approximately 30 ft. long and 8 ft. in diameter.

One of the advantages of the system is that very little space is occupied by the plant as the storage vessels are placed within the footings of the building columns, below the sub-basement floor level. This reduction in floor area is a considerable advantage in metropolitan districts where space is at a premium.

The writer is indebted to Sulzer Bros. of London for data and diagrams used in this article.

Various Types of

By E. W. ROBEY

Chief Engineer, Underfeed Stoker Co., Ltd.
LONDON

The author describes various types of water-sealed and sluice-type ash conveyors and discusses typical applications. In certain localities in England, there is a market for graded ashes and a screening plant used for this purpose is described. A novel development of the water-sealed type of conveyor is also described. In this conveyor a series of buckets, mounted on rollers and joined by rubber connections, forms a continuous moving trough in which the water remains at a fixed level. The particular advantage of this scheme is that there is no relative movement between any part of the conveyor and the material being handled which results in notably low maintenance.

THE handling of ashes in a boiler plant has always been an arduous and dirty job, and, due to the very abrasive nature of the material, mechanical means used for its disposal tend to be expensive in maintenance.

To obviate dumping the ashes and the consequent dust and fumes caused by this method, water-sealed chain conveyors have been used in many important power stations. This type of conveyor has the advantages of simplicity, dependableness and low labor and power requirements. In typical installations, the average power required is not more than 2 h.p. The ashes are fed continuously from the furnace to the conveyor trough and elevated by the conveyor into a storage bunker ready for easy removal. The water-sealed feature of this conveyor eliminates the possibility of air leakage into the furnace incident to the removal of ashes.

In many cases, however, particularly in older boiler plants having a number of units variously arranged, this type of conveyor is not so applicable. To meet this condition, the sluice type conveyor was developed. However, its many advantageous features rapidly broadened its field of application and today it is being used extensively in practically all types of plants.

This conveyor consists of a trough of semi-cylin-

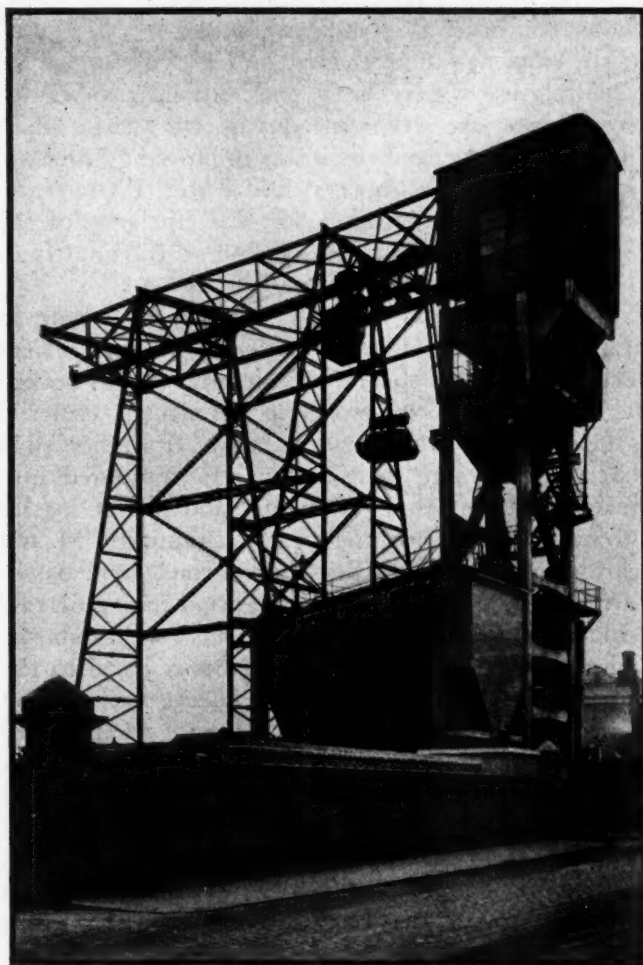


Fig. 1—Telpher and screening plant for screening ashes into saleable sizes

drical section, either built up in cast-iron sections or constructed in ferro-concrete, with a lining of hard cast-iron plates. These lining plates when properly fitted offer the least resistance to the flow of water and have a long life. The ashes are discharged continuously from the stoker through connecting chutes, conveyed down the ash trough by a continuous stream of water and delivered into an ash pit or sump, preferably exterior to the boiler plant. In order to effect an efficient air seal, special sealing doors are fitted in the trough at each side of the boiler; these doors float on the water and are automatic in action.

On reaching the ash sump, the water is separated from the ashes by suitable screens and flows into a suction chamber from which it is pumped back to the top end of the trough, or troughs. Wear in the pipes is very small, and as the pumps are the only moving part of the system, replacements seldom entail more than a new pump impeller and bushes.

Ash Conveyors Used in British Power Station Practice . . .

The water, forming a closed circuit, usually attains a temperature of about 140 deg. fahr., evaporation being made up when necessary.

With this system it is possible to serve boilers on different center lines and change the direction of trough as may be necessary. It is advisable not to install curves of less than 9 ft. radius.

The quantity of water and the power required depend upon the design of each particular plant, and no hard and fast rules can be given, but these factors remain constant for varying quantities of ashes below the maximum, as just as much power is required in a given plant to move 2 tons of ash per hour as to move 10 tons per hour; hence, the larger plants show a better balance sheet.

Ash conveying plants of this type are illustrated in Figs. 2, 3 and 4, which show the ash chutes and troughs in typical installations. An arrangement of Pumps and Motors is shown in Fig. 5. In Fig. 2, the ash chutes are of cast iron and the cylindrical chutes are for the discharge of grit and soot, the former being discharged into the trough and the soot into a separate system—to be mentioned later.

The following are the main points in the design of the conveyor: The trough is built of reinforced concrete or other suitable material, 2 ft. 0 in. wide by 2 ft. 0 in. deep at the top end, and arranged to slope towards the sump at an inclination of approximately 1 in 50, although numerous plants are now working with steeper or flatter slopes than this. In



Fig. 2—Plant equipped with sluicing conveyor. View shows cast-iron ash chutes and soot and dust pipes

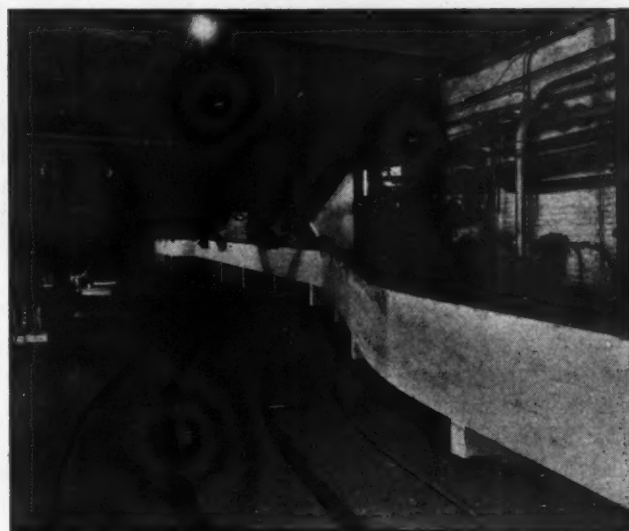


Fig. 3—View of sluicing trough in boiler room basement showing flexibility of arrangement

general, the steeper the slope can be arranged, the less is the quantity of water required, and hence the lower the power requirements. The concrete trough is lined throughout its entire length with cast-iron, semi-cylindrical plates, or, as an alternative, the complete trough can be built up in cast-iron sections, doing away with the necessity of any concrete work. This is more applicable in cases where it is necessary to build the trough above the basement floor level.

Between boilers, there is fitted a floating seal of the balanced door type, mentioned previously, and the whole trough is covered with mild-steel plates to make it airtight, openings being left for connecting chutes to the various combustion chambers. A pipe line connects the upper end of the trough to the pumps. This is usually in duplicate and housed next to the storage sump below water level, so as to be self-priming and to obviate long suction pipes. Either vertical or horizontal spindle types may be used. A clean water supply should be furnished for the pump neck bush and packing glands to keep these free from grit. The pump impellers are usually of cast-steel, unless salt water is being used, when zinc-free bronze impellers are employed. The pump casing should be lined with renewable, hard, cast-iron plates.

A certain amount of silt and fine ash is bound to be carried through the screens, so the suction



Fig. 4—View of sluicing trough and ash chutes

chamber should be designed for ready access for cleaning purposes. The velocity of water through the suction pit should be small, so that the maximum of silt carried by the water can be deposited.

Ash can be reclaimed from the sump at any time, and by various means to suit each particular plant, but preferably by a grab bucket.

The following diagrams show various modifications of this type of conveyor:

Fig. 6 shows the layout of a typical sluice conveyor under four boilers, the ash being reclaimed from the sump by means of a hoist and grab and deposited into trucks.

Fig. 7 shows lay-out of sluice conveyors under four lines of boilers, each trough delivering into a common trough which delivers into the sump outside the house. In this case the reclaiming is done by means of a crane and grab, and the ash deposited into cars.

Fig. 8 shows an interesting application of this type of conveyor, the boiler house being on a higher level than the surrounding ground. The sluice is arranged to deliver into an overhead bunker, having two compartments, so that when one has been filled with ash it can be allowed to drain while the other compartment is being filled. The ashes can be discharged from the bottom of the bunker direct to railway cars, thus eliminating any special reclaiming equipment.

A modification of this type of conveyor enables not only the removal of the ashes from the boiler house but also their delivery into a silo above ground, which is accomplished by means of one pump only, there being no other moving mechanism. A typical diagrammatic arrangement of such a plant is shown in Fig. 9.

The mixture of ashes and water instead of being delivered into a sump is discharged into a comparatively small circular swirl pit, or mixing

chamber, whence the mixture is pumped direct into the silo above ground. This silo, or bunker, is fitted with suitable screens through which the water returns by gravity to the upper end of the trough. If the plant is in continuous operation it is advisable that the bunker be designed with two separate compartments, so that while one is being filled the other can be draining to avoid the discharge of an unnecessarily large amount of water with the ashes.

The pumps for this service should be of the fullway centrifugal type, and, to avoid excessive erosion, the impellers and the lining of the pumps should be of manganese steel. Such a lining of this material will last normally for 1000 to 1500 hours continuous operation, and, during this period, the pump may have passed 20,000 to 50,000 tons of ashes.

Provision to prevent the choking of the suction pipe by large pieces of clinker and other material is necessary and this is usually provided in the shape of a grid in the bottom of the ash hopper, designed to prevent passage in the trough of pieces larger than 6 in. cubes. Access doors are arranged above the grids in the chutes connecting the ash hoppers to the troughs so that large pieces remaining on the grid can be broken through into the conveyor.

It is frequently found that the greater part of the cost of handling the ashes is incurred in the final disposal from the sump or silo to the storage ground, and any attempt to make the ashes a marketable commodity warrants attention. One means to this end is the delivery of the ashes screened into various sizes and Fig. 1 shows a plant for this purpose. The ashes are discharged into a sump, whence they are raised by means of a telpher machine and grab into a hopper. Thence, they are delivered in a substantially uniform flow by means of a rotary feeder to the rotary screens shown in Fig. 9. In this case, the ashes are delivered in five sizes into an equal number of hoppers arranged beneath the screens. It is found that whereas previous to this installation



Fig. 5—Arrangement of conveyor pumps and motors

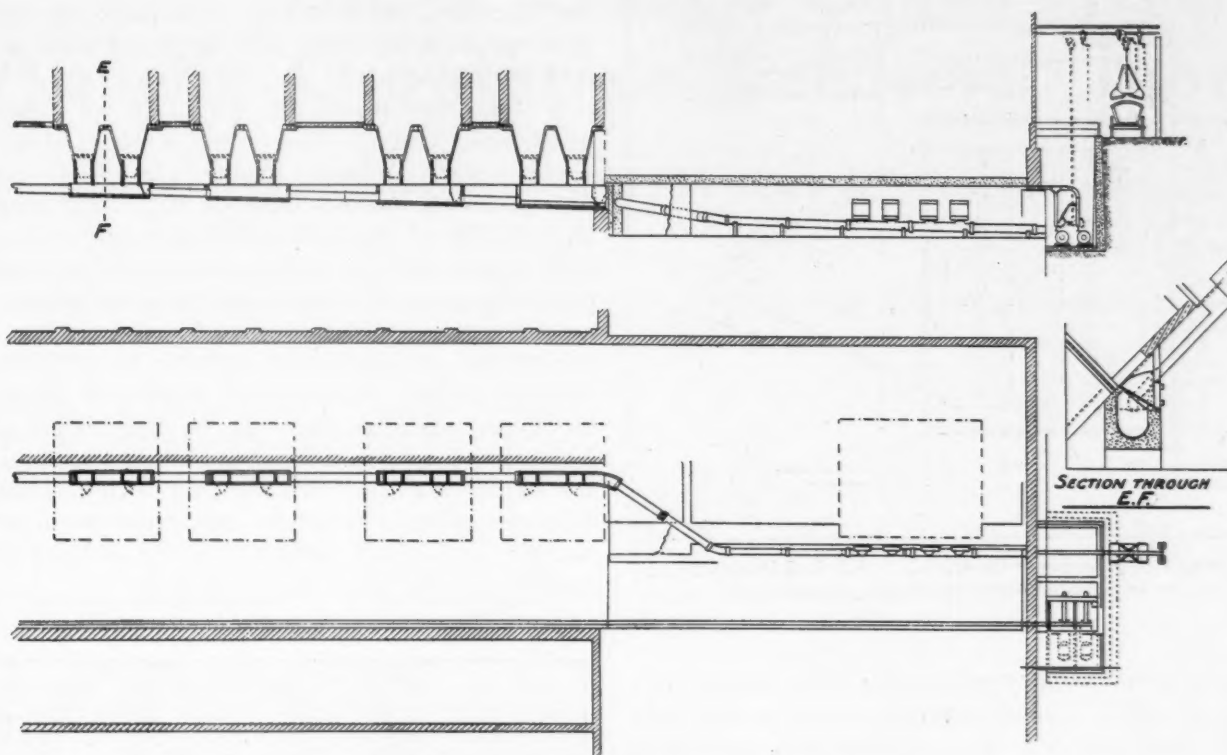


Fig. 6—Typical sluice conveyor layout for four boilers. Ash is removed from sump by grab bucket and deposited in trucks

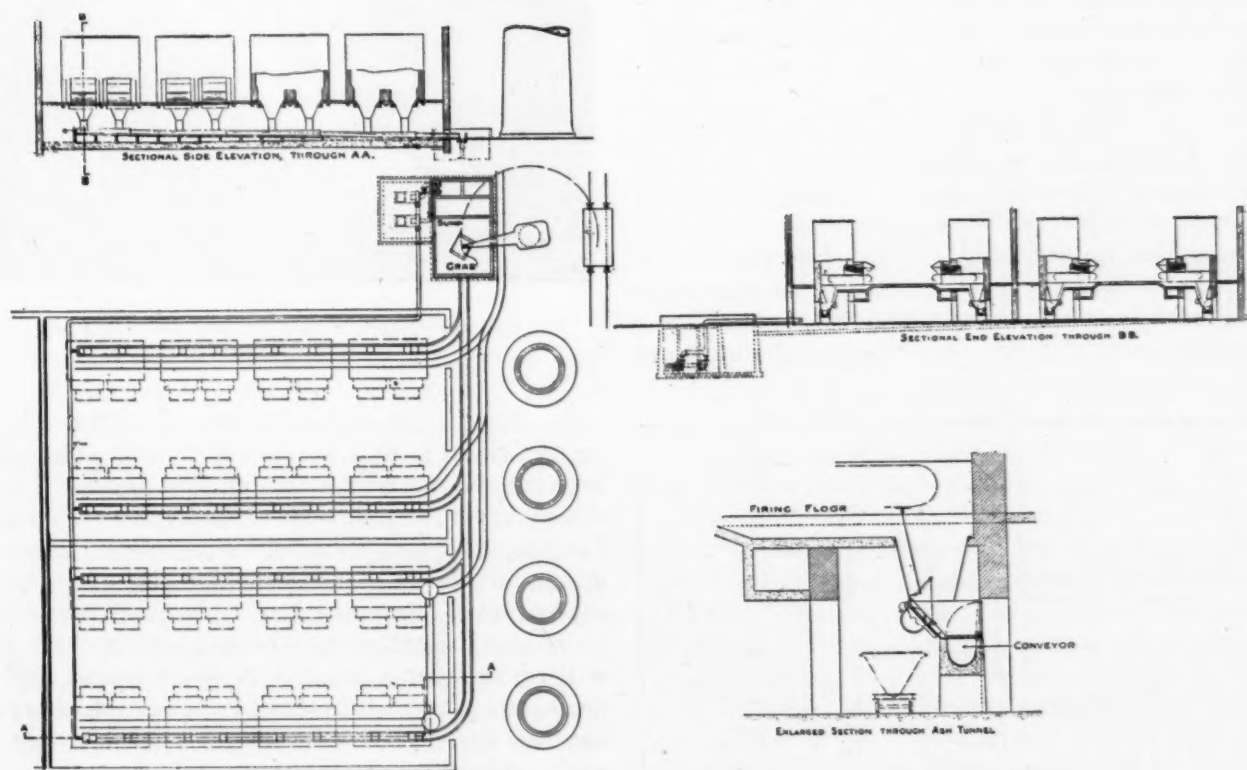


Fig. 7—Sluice conveyor layout for four batteries of boilers. The trough serving each battery delivers into a common trough connecting to the sump

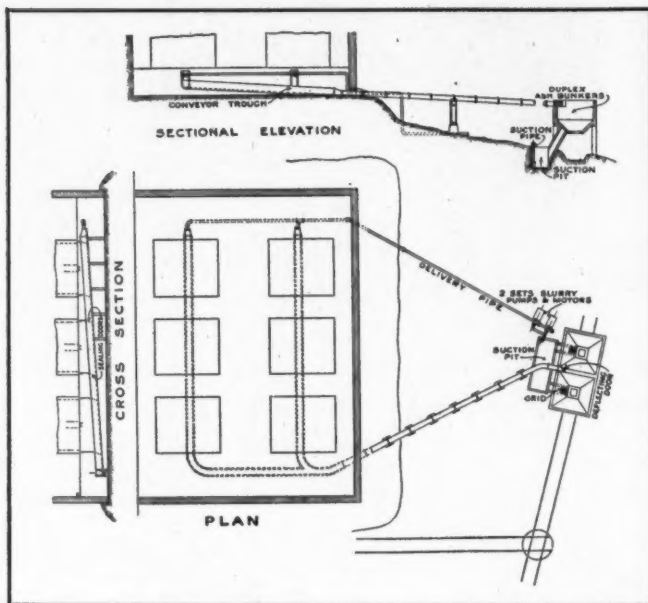


Fig. 8—Sluicing conveyor installation. Ash is delivered directly to an outside bunker at a lower ground level

it was necessary to pay to have the ashes taken away, there is now a ready market for screened ash. Each screen is 2 ft. 6 in. in diameter and 30 ft. long and has a capacity of 10 tons per hour, or 20 tons for the plant. The capacity of the motor for each screen is 8 hp.

Any system involving the screening of ashes for sale must include means for maintaining the separation between the soot and the ashes as, if these two products are mixed, the value of the ashes is materially depreciated.

This separation is accomplished in one case as follows: An ash pipe line is installed on each side of the boiler house connected to chutes leading from various parts of the boiler. These pipe lines lead to a mixing chamber in the middle of the basement and a pump drawing from there discharges the soot with the water which has been used to carry the soot down the pipes into a filter which is located underneath the

telpher track. The filter bed is merely a layer of ashes through which the water percolates. When the filter bed becomes foul, it is lifted up by the grab and dumped, and a new supply of ashes deposited in its place.

A development of the first type of conveyor mentioned, namely, the water-sealed chain conveyor, is the continuous bucket type which consists of a series of buckets without ends fixed between two strands of chain to which they are rivetted in such a way that the buckets and the chain together may form an endless belt which can be operated as an ordinary scraper chain or rubber band. The ends of the buckets are joined together by rubber connections so that when a series of buckets are in the horizontal position they can be filled with water forming a water trough, in which the ends of the ash chutes leading from the combustion chambers may be sealed. The chains are fitted with rollers running on a track, which may be inclined at an angle of 50 deg. with the horizontal.



Fig. 10—Rotary screening plant for sizing ash

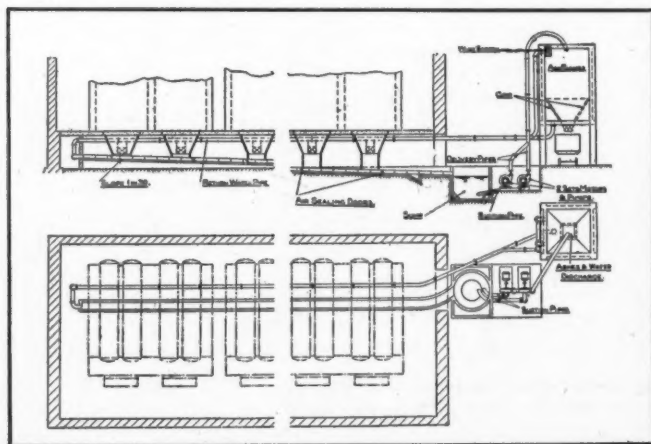


Fig. 9—Sluicing conveyor installation of hydraulic type. The ashes and water are pumped from a small sump or pit to an overhead silo

The advantages of this conveyor over the ordinary scraper chain is that there is no relative movement between the material being handled and any part of the conveyor, so that wear is reduced to a minimum. Further, the provision of the rollers insures a minimum power requirement for the operation of the conveyor. Provided a suitable quality of rubber is used for the connections between the buckets, they will operate for a lengthy period without replacement, and plants of this type have been in operation for over three years without material deterioration of this portion of the plant.

In conclusion, it must be said that any plant for handling so abrasive and corrosive a material must be of rugged design and, as it is usually in the care of unskilled operators, it must be of the simplest possible character.

Use of Chlorine Gas to Prevent Aquatic Growths on Condenser Tubes

A recent development in British Power Station Practice

By DAVID BROWNLIE, London

The chlorination of condensers for slime removal on a continuous basis was first practiced extensively in England. Mr. Brownlie discusses the development of this practice in England from the time of its inception in 1922 up to the present. The first installations in the United States were made about four years ago. Since that time there has been developed in this country an automatic, intermittent condenser chlorinating process which has been in satisfactory operation in two plants for a period of one to two years and which is now in operation or contracted for by half a dozen of the largest utility companies in the country. This later development was necessary to adapt this process to American conditions. A great many of the English condenser chlorinator installations are on recirculating systems where a comparatively small amount of chlorine, per thousand gallons of water recirculated, is required. While there are a great many recirculating systems in the United States where continuous chlorination is feasible and advantageous, the really large power plants of the utility companies usually do not recirculate and are very often users of highly contaminated cooling waters which have exceedingly large chlorine demands and which it would not be commercially feasible to chlorinate continuously. Hence the development of the intermittent process which meets the requirements of non-recirculating plants with a comparatively small consumption of chlorine.

vacuum means 1 per cent increase in steam consumption by the turbine.

In one typical case in Great Britain, that of the Borough of Hackney Electricity Station, London, which was the first power station in the world to adopt the chlorination practice, the net saving obtained by sterilizing the cooling water, (from the Thames), is approximately \$8,000.00 per annum. This is a comparatively small station with a capacity of 6000 kw., using 48,000,000 gal. of cooling water per 24 hr.

Admittedly the subject of organic growths is more troublesome in some stations than others, often for no very apparent reason, although contamination of the water with sewage and organic material and the average atmospheric temperature are factors which generally affect the condition. However, few power stations in the world are entirely free from the trouble as most water is swarming with various forms of life. Two other important advantages of sterilization with chlorine gas are the prevention of weeds inside cooling towers and the elimination of shellfish, such as mussels and limpets, in cooling water pipes when sea water or brackish water is used for cooling.

A description of the chlorination method for power plants is opportune because the British Electrical and Allied Industries Research Association, 36-38 Kingsway, London, W.C.2, has just issued a publication "The Prevention of Trouble due to Aquatic Growths in Condenser Systems with Special Reference to the Destruction of Mussels", being a critical resume of the subject by D. V. Onslow. This has appeared as a result of a number of members of the Association having asked for assistance and information concerning the prevention of the trouble caused by the accumulation of mussels and other growths in the pipes leading to the condensers or in the condenser tubes themselves. Accordingly a questionnaire was sent to condenser manufacturers and to certain power stations known to have experienced difficulties in this connection.

The present report is the result, the gist of the matter being that chlorine gas is the most satisfactory method of preventing the trouble, a fact already well known to many people for a number of years

THE continuous sterilization of cooling water with a measured trace of chlorine gas originated in England in 1922 where it was developed by the Paterson Engineering Company, Ltd., of London. In the treatment developed by this company, and known as "Chloronome," the chlorine gas is delivered to the condenser water from cylinders or drums, generally in the proportion of about 1 part per 2,000,000, which proportion can be varied as required to prevent the deposition of non-conductive, slimy algoid and other aquatic growths on the condenser tubes. As a result the highest vacuum in the turbine can be maintained without the troublesome process of cleaning the condenser tubes at frequent intervals, a costly practice entailing a slow reduction in turbine efficiency due to appreciable loss of vacuum, the loss incidental to the shut-down of expensive equipment, and the cost of labor for cleaning. The extent of this loss is evident from the fact that approximately $\frac{1}{4}$ in. drop in the

past. However, although the report contains nothing new, it is interesting as being an entirely independent summary of the situation especially insofar as the opinions of users are concerned.

As is already well known, chlorine gas was widely used before 1922 for sterilization purposes, and its field of application to-day includes the treatment of public water supply, sewage and sewage effluents, and water for swimming baths. Although the historical record is not entirely clear, it appears that the use of chlorine gas for sterilizing drinking water was first suggested in 1903 by a British officer, Lieutenant

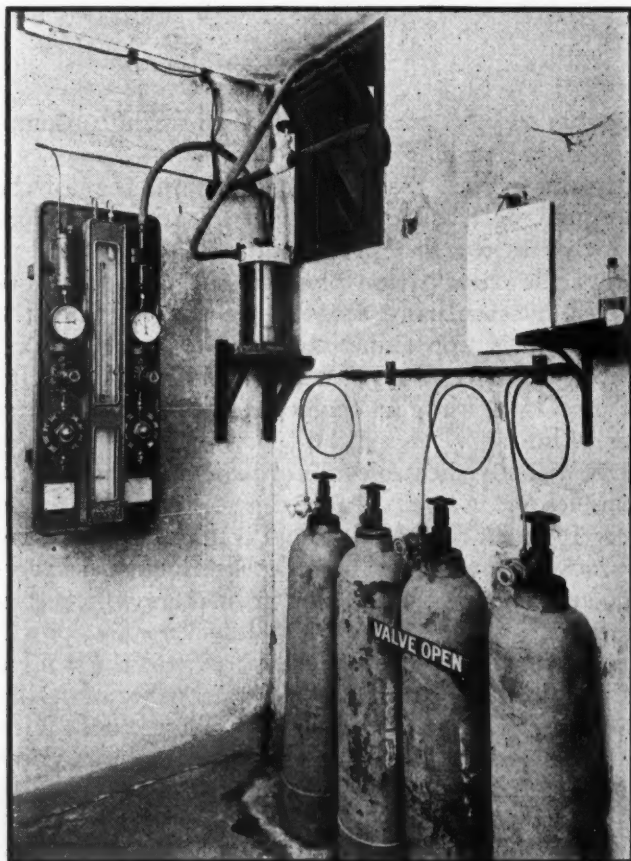


Fig. 1—Installation of chloronome apparatus at the Hackney Station, London, made in 1922—the first installation of this apparatus to be made in a power station

Nessfield, of the Indian Medical Service. However, it does not seem to have been employed on a practical scale until about 1910, when it was used by Major Darnall, M.D., U. S. Army Medical Corps. At about this time, the Paterson Engineering Co. Ltd., in Great Britain was using equipment based on the application of bleaching powder (calcium chloro-hypochlorite or sodium hypochlorite). Sir Alexander Houston of the Metropolitan Water Board, London, also had used bleaching powder in 1905 for drinking water to fight an epidemic of typhoid fever at Lincoln. In 1917, the Paterson Company introduced the "Chloronome" apparatus using pure liquid chlorine, and the same year this was adopted by the Metropolitan Water Board, and came into general use for public water supply. As regards the specific application of chlor-

ine gas to power stations, however, the Hackney station application in 1922 was the first installation. This station was particularly troubled with organic growths on the condenser tubes, and the chlorine method was adopted at the suggestion of Sir Alexander Houston because of the satisfactory experience at the Metropolitan Water Board for combating algae and other water organisms.

After the installation of the chloronome apparatus at the Hackney station, L. L. Robinson, chief engineer stated in an article that with the 6,000 kw. plant the original labor cost of cleaning the condensers averaged \$26.00 per week all the year around. With the Chloronome apparatus, the total cost, labor and chlorine was \$12.00 per week representing a reduction of about \$730.00 per annum. Because of the much better vacuum maintained, the saving in coal per ton amounted to \$140.00 per week, that is \$7280.00 per annum, and there was also a reduction in operating costs of pumping as less circulating water was required. There is also given in the article from which these figures are taken a series of curves indicating load, river temperature and vacuum which show clearly the substantial net saving obtained to be at least \$8000.00 per annum.

Interesting also is the report of A. E. McKenzie, Chief Engineer of the Wimbledon Corporation Electricity Department (London) who states that he installed a Chloronome plant six years ago (1924) treating 30,000,000 gal. of water per 24 hours. Previously the custom had been to brush out the tubes of the condenser two or three times a week but the chlorinating plant however stopped the breeding of algae so that the condensers are now opened only once every three or four months to clean out fine mud, while the vacuum had been on the average at least 1 in. higher throughout the 6 years.

As regards the special subject of mussels, the Chloronome equipment is dealing with this trouble at the Chatham, Portsmouth, and Devonport Dockyard Power stations, and the plant of the Llanelly Electric Power Co. in South Wales.

In many cases it is the custom to clean out mussels by hand, closing down at intervals, killing the fish by strong poison, even to the extent of using sulphuric acid, and then removing all the shells. Generally mussels and limpets collect in the warmer portions of the pipe circuit, especially the discharge end, while air locks are suitable breeding grounds and the inlet pipes also are often badly affected. The beneficial action of chlorine seems to be largely the killing of the minute organisms on which the mussels live.

Altogether about 60 power stations in Great Britain and abroad are now operating with Chloronome apparatus, some of these installations being as follows: (the figures in parenthesis indicate the water treated in gallons per 24 hours) Charing Cross Electricity Supply Co. London, (72,000,000), South Wales Power Co. Ltd., (72,000,000), Compagnie Continent-

ale du Gaz, Lille, France (63,360,000), Bristol Corporation (48,000,000), Rotherham Corporation (48,000,000), Poplar, London, (48,000,000), West Ham, London, (42,000,000), Birmingham Corporation (36,000,000), Peterborough (36,000,000), St. Marylebone, London (28,800,000), and a number of British Government Dockyard power plants, including, as already mentioned, Devonport (24,000,000), Portsmouth (24,000,000) and Chatham (14,400,000).

The Paterson Chloronome is supplied in three types, the "Pulser", the "Manometer", and the "Automatic". In general the "Pulser" is used for small installations taking less than 10 lb. of chlorine per day, equivalent roughly to treating say 21,000,000 gal. of normal water in this time, although, of course, much depends on the nature of the water. For power station work the "Manometer" is the type almost always used, taking any amount of chlorine desired, above 10 lb. per day. In both these machines,

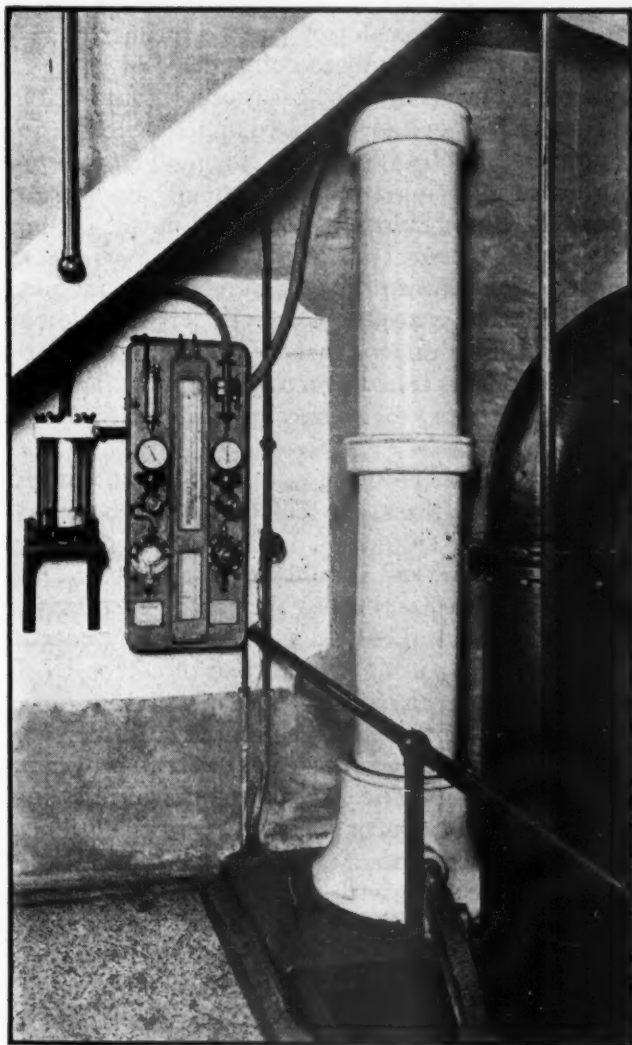


Fig. 2—Chloronome plant and absorption tower at Beckton Gas Works, London

the amount being added is accurately controlled by a hand valve which is all that is required, since such a large bulk as represented by cooling water in power stations, with a steady flow, does not vary much

within a short period. The "Automatic" however is a special instrument, in which the control of the chlorine gas admission is completely automatic, by means of the differential head set up in a venturi tube. This type is particularly suited for cases such as city

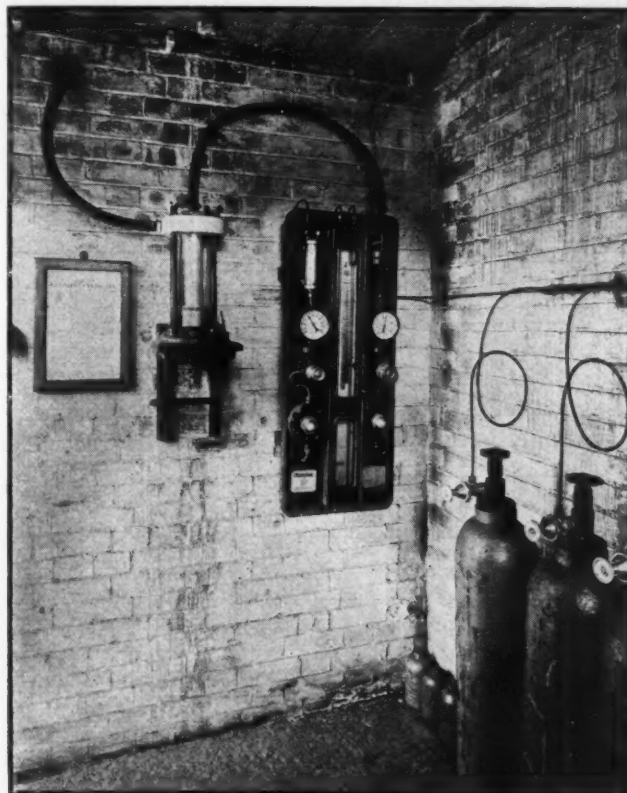


Fig. 3—Chloronome installation at Poplar Power Station, London

water reservoir work where the volume of water varies considerably according to the demand, the amount of chlorine gas also varying accordingly to keep the addition always at some pre-determined figure.

In all three types of "Chloromone" the instrument comprises essentially a control board or panel arrangement of cast aluminum, which is connected to standard cylinders or drums of liquid chlorine. The board includes a filter for the chlorine, and two pressure reducing valves, in series, the first of which reduces the pressure of the gas drawn off from the cylinders, from about 80 to 120 lb., to 20 lb. per sq. in., while the second controls and reduces it very accurately to 10 lb. There is also an arrangement of gages and meters to show the amount of chlorine passing, and a control valve to regulate the exact quantity administered. The chlorine gas bubbles through a patent seal of concentrated sulphuric acid, which prevents any moisture passing back into the apparatus from the water and keeps the chlorine dry and non-corrosive and is discharged into a vertical absorber, consisting essentially of a glazed earthenware tower filled with pumice stone and having in the top a water distributing tray. The chlorine is thus completely absorbed, and the water runs out continuously at the bottom as

a strong solution of chlorine which passes direct by a distributor to the main supply of the cooling water at the pump suction. This latter is highly important because it is otherwise a difficult matter to add chlorine gas to a huge bulk of water such as 50,000,000 gal. per 24 hr. at the rate of 1 part per 2,000,000 and obtain an entirely uniform solution of the chlorine.

With regard to the details of the "Manometer"

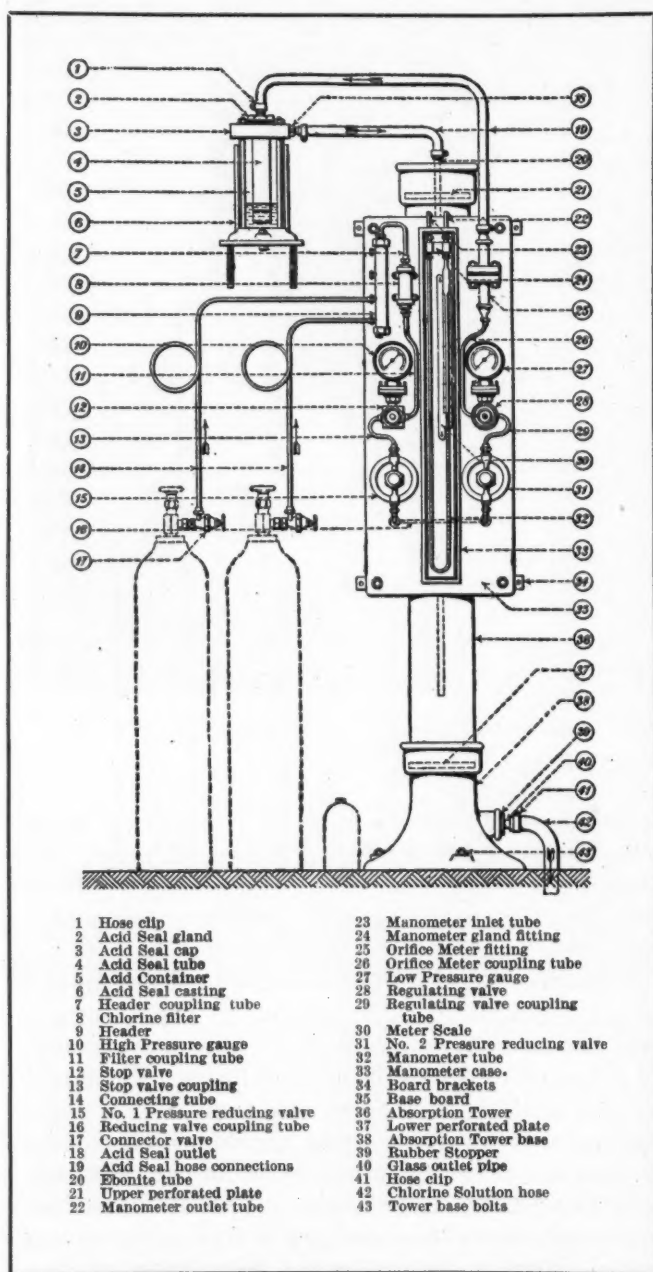


Fig. 4—Paterson Chloronome (manometer type)

type illustrated in Fig. 4, the flow of the chlorine gas is measured by the difference in pressure on either side of a restricted orifice, connected to the cylinders of chlorine by flexible copper tubing. The cylinders for larger installations are arranged in groups and connected through headers with the chlorine gas; drums of 1500 lb. capacity each may be used in the same way. From the second pressure regulating valve, the chlorine gas, at 10 lb. pressure, passes through a

special silver diaphragm plate having an orifice of pre-determined size with a connection from each side to a manometer tube, the difference of level of a liquid in this tube showing, on a graduated scale corresponding to the orifice, the rate of flow of the chlorine gas in pounds per hour. From this point, the chlorine gas bubbles through the strong sulphuric acid and passes to the earthenware absorption tower.

In order to control the chlorination treatment and insure, for example, a very slight excess of chlorine in the final water, various simple tests can be used. The best and most accurate is the use of ortho-tolidine which gives a yellow color with the minutest trace of free chlorine. For this purpose a simple portable test apparatus is supplied complete, in a 2½ lb. case, containing three colorless glass tubes, two of which are standards filled with untreated water so as to avoid any possibility of error due to natural color in the water. By filling the third tube with chlorinated water and adding a trace of ortho-tolidine solution the amount of free chlorine can be estimated at a glance by means of standard color glasses.

In Great Britain, chlorine gas is usually supplied in solid drawn steel cylinders, tested up to 600 lb. per sq. in. pressure, holding about 70 to 75 lb. of liquid chlorine, and having a total weight of 160 lb. For large users, liquid chlorine is supplied in steel drums each holding about 1500 lb.; it is also possible to transport liquid chlorine in special 10-ton tank trucks. Liquid chlorine is also sent in cylinders from Great Britain to many different parts of the world in standard steel cylinders tested in accordance with Board of Trade Regulations, each containing about 65 lb. of chlorine.

Although liquid chlorine is, of course, not affected by climatic conditions, the temperature of the building in which the cylinders are kept should be about 70 to 75 deg. fahr. and should not be allowed to fall below 55 deg. fahr. as the flow then becomes sluggish. Any very slight leak of chlorine from a cylinder is easily detected by using a small pad of cotton wool dipped in strong ammonia (0.880), which at once gives dense white fumes of ammonium chloride.

Although the use of chlorine gas has been proved to be much the best practice, there are other interesting methods for the treatment of cooling water mentioned in the report referred to in the first part of this article. Thus, in connection with the removal of mussels, investigations carried out at the Portobello power station of the City of Edinburgh Electricity Department (Scotland) have shown that if mussels are subjected to a higher temperature than normal for a short period, the result is beneficial! Consequently, at Portobello the method employed is to reduce the amount of circulating water for short periods of 12 to 14 hr. at regular intervals so that the temperature of the outlet water rises to 89 to 90 deg. fahr. As a result many of the mussels loosen their hold and are swept away, each section of the pipe work being

(Continued on page 55)

The Pressure-Volume-Temperature Relation of Gases

(Continued from page 32)

the general relation to Berthelot's equation of state, we obtain,

$$\left(\frac{\partial u}{\partial v}\right)_T = A T \left(\frac{p}{T} + \frac{2a}{T^2 v^2}\right) - A p$$

Since $a = 27 R^2 T_c^3 / 64 p_c$ for Berthelot's equation, we have

$$\left(\frac{\partial u}{\partial v}\right)_T = \frac{27 A R^2 T_c^3}{64 p_c p T v^2}$$

For atmospheric air $T_c = 132.4$ K and $p_c = 39.3$ atm. Also, $R = 0.08206$ liter-atm. per gram-mole per deg. cent. and $A R = 1.985$ cal. per gram-mole per deg. cent. Hence, for air,

$$\left(\frac{\partial u}{\partial v}\right)_T = \frac{4058}{T v^2}$$

For air under one atmosphere and at the temperature of melting ice ($T = 273.1$), we have for normal density $v = 22.4115$ liters per gram-mole. Substituting these values in the above relation and also the specific volumes for 10 and 100 times normal density, we obtain for the change in internal energy in calories per liter change in volume of any mass of air at zero centigrade:

Internal energy change, cal. per liter change in volume	Times normal density
0.0296	1
2.96	10
296.	100

As indicated by these values, the change in internal energy of air with change in density is negligible at low and at moderate pressures; but at pressures over 1000 lb. per sq. in., the change in internal energy becomes appreciable. It is this change in internal energy in addition to the variation in the product of the pressure and volume with change of pressure that makes possible certain industrial processes for the separation of atmospheric air into its components.

References

Partington and Shilling's book on the Specific Heats of Gases gives a long list of equations of state which have been proposed by various investigators to represent the pressure-volume-temperature relation of real gases. An interesting discussion of this subject will be found in the Chapter on The Critical State in Callendar's book on the Properties of Steam. For the pressure-volume-temperature relation of a number of gases, see U. S. Bureau of Standards Circular No. 279 entitled Relations between the Temperatures, Pressures and Densities of Gases. Also see U. S. Bureau of Standards Scientific Paper No. 529 on A Review of the Literature Relating to the Normal Densities of Gases. The International Critical Tables contains many data on the properties of gases.

High and Net Heat Values of Fuels

(Continued from page 26)

11 is small, in fact, is much smaller than the errors that creep into the most carefully made boiler tests. On the other hand, the difference between the values in column 9 and those given in columns 10 and 11 is quite marked, especially with the fuels having high hydrogen contents. Thus, the difference in efficiency for the West Virginia coal is 2.6 per cent, whereas for Arkansas natural gas it is 8.6 per cent.

The net or low heat value can be obtained by means of the following equation:

$$(1) \text{ Low heat value} = \text{high heat value} - \frac{H \times 9 \times 1040}{100}$$

percentage by weight in fuel as fired.

The last constant may be 1040, 1055 or 1080 depending upon which of these three values one wishes to use.

For conversion of the efficiency based on high heat value to efficiency based on low heat value the following equation can be used:

$$(2) \text{ Efficiency based on low heat value} = \frac{\text{Efficiency based on high heat value} \times \text{high heat value}}{\text{Low heat value}}$$

In the above equation both efficiencies are expressed in percentages.

The use of low heat value for the calculation of efficiency of steam generating units seems more logical than the use of high heat value. Surely the steam generating unit should not be charged with heat which it is impractical to absorb. In fact, designers of steam generating units exert every effort to create designs which will prevent the absorption of any of the heat by condensing the water vapor in the products of combustion.

However, the use of low heat value in the computation of the performance of steam generating units has two serious drawbacks. The first one, which has already been discussed, is the lack of agreement as to which heat value is to be used to represent the heat released by the condensation of the vapor and cooling it down to calorimeter temperature. The second drawback is that, in addition to the high heat value, it is necessary to have an ultimate analysis of the fuel, or at least the hydrogen content of the fuel for the computation of low heat value. Such analysis is complicated and expensive, and comparatively few laboratories have facilities to make them accurately. On the other hand, the determination of the high heat value is fairly simple and can be made accurately by a careful man after a comparatively short period of practice with the calorimeter. The fact that the high heat value can be obtained directly with the calorimeter is probably the principal reason for the general use of this value in this country in computing the efficiencies of steam generating units.

How to Measure Steam Quantities

By B. J. CROSS, Combustion Engineering Corporation, New York

THE flow of steam may be measured by the same means used to measure air quantities as described in the preceding article of this series. The same formulas apply and the same type of apparatus may be used except that it must be modified for use with the higher pressures and temperatures encountered with steam.

Common forms of steam meters are shown in Fig. 1. Because of its simpler construction and easier installation the orifice is probably the most common although the flow nozzle and the venturi meter are widely used for steam flow measurement. The throats of the flow nozzle and of the venturi meter and the orifice plate must be accurately machined to size and should be made of wear-resisting material.

In the measurement of steam flow, the pressure differences are usually measured with a differential mercury manometer and are expressed in inches of mercury. The basic formula, velocity (feet per second) = $\sqrt{2gh_s}$ must therefore be modified so that h_s , the head in feet of steam, may be expressed in inches of mercury.

$$V = \sqrt{2g \frac{h}{12} \times \frac{d_m^4}{d_s^4}} = 8.02 \sqrt{\frac{h}{12} \times \frac{845.5}{d_s^4}} = 67.32 \sqrt{\frac{h}{d_s}}$$

d_m = density of mercury—lb. per cu. ft.

d_s = density of steam—lb. per cu. ft.

h = differential head in inches of mercury

As it is usually desired to know the flow of steam in pounds per hour, the equation may be further modified as follows:

$$Q = \text{weight of steam (lb. per hr.)} =$$

$$\text{Area (sq. ft.)} \times 3600 \times 67.3 \times d_s \times \sqrt{\frac{h}{d_s}}$$

If a unit area of 1 sq. in. be taken the equation then becomes:

$$Q = \frac{3600}{144} \times 67.3 \times d_s \times \sqrt{\frac{h}{d_s}} \text{ or } Q = 1683 \times \sqrt{hd_s}$$

The chart on the opposite page has been constructed from this equation. It gives the flow of steam in pounds per square inch of effective area per hour corresponding to different pressure differences in inches of mercury and for different densities of steam. To use this chart, it is necessary to know the throat area of the meter, the density of the steam and the pressure difference across the meter. In the flow nozzle and venturi, the area used is the actual measured area. In the orifice meter, the actual area must be corrected using the factor C corresponding to the

ratio of the orifice diameter and the pipe diameter $\frac{D_2}{D_1}$ as shown in curve of the small insert chart.

The density of the steam may be obtained from standard steam tables, the pressure and superheat being known. It is expressed in pounds per cubic foot.

The pressure difference may be measured with a mercury manometer. Care should be taken that both legs of the manometer above the mercury be filled with water. For this reason small finned radiators are usually attached to the manometer legs close to the steam pipe.

When the pressure difference is kept within 1 or 2 per cent of the initial pressure, an accuracy of 2 per cent is ascribed to these meters. If the pressure difference exceeds this figure, a further correction must be applied due to the change in volume of the steam.

As an example in the use of the chart, assume the following conditions:

Pipe diameter D_1	6 in.
Orifice diameter D_2	4 in.
Ratio $\frac{D_2}{D_1}$.....	.667
Orifice coefficient C.....	.68
Effective orifice area.....	8.55 sq. in.
Pressure differential.....	3.5 in. mercury
Steam pressure—gauge.....	200 lb. per sq. in.
Steam temperature.....	640 deg. fahr.
Density, lb. per cubic feet.....	.338
Steam flow—lb. per hr. per sq. in.....	1830
Steam flow—lb. per hour.....	15640

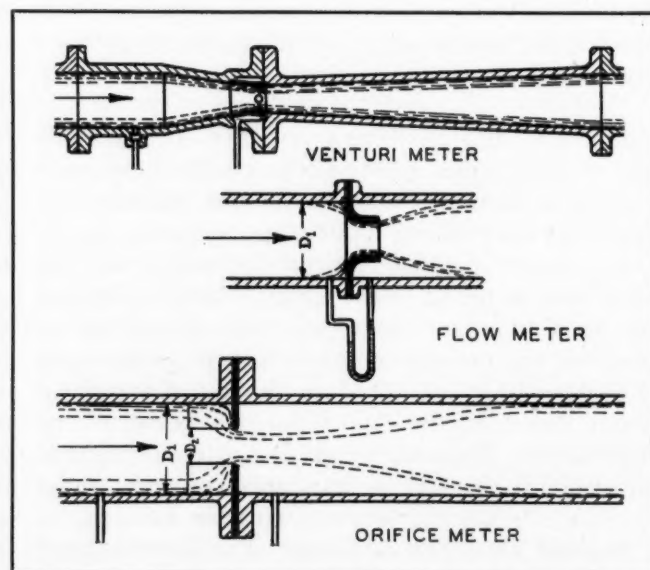


Figure 1

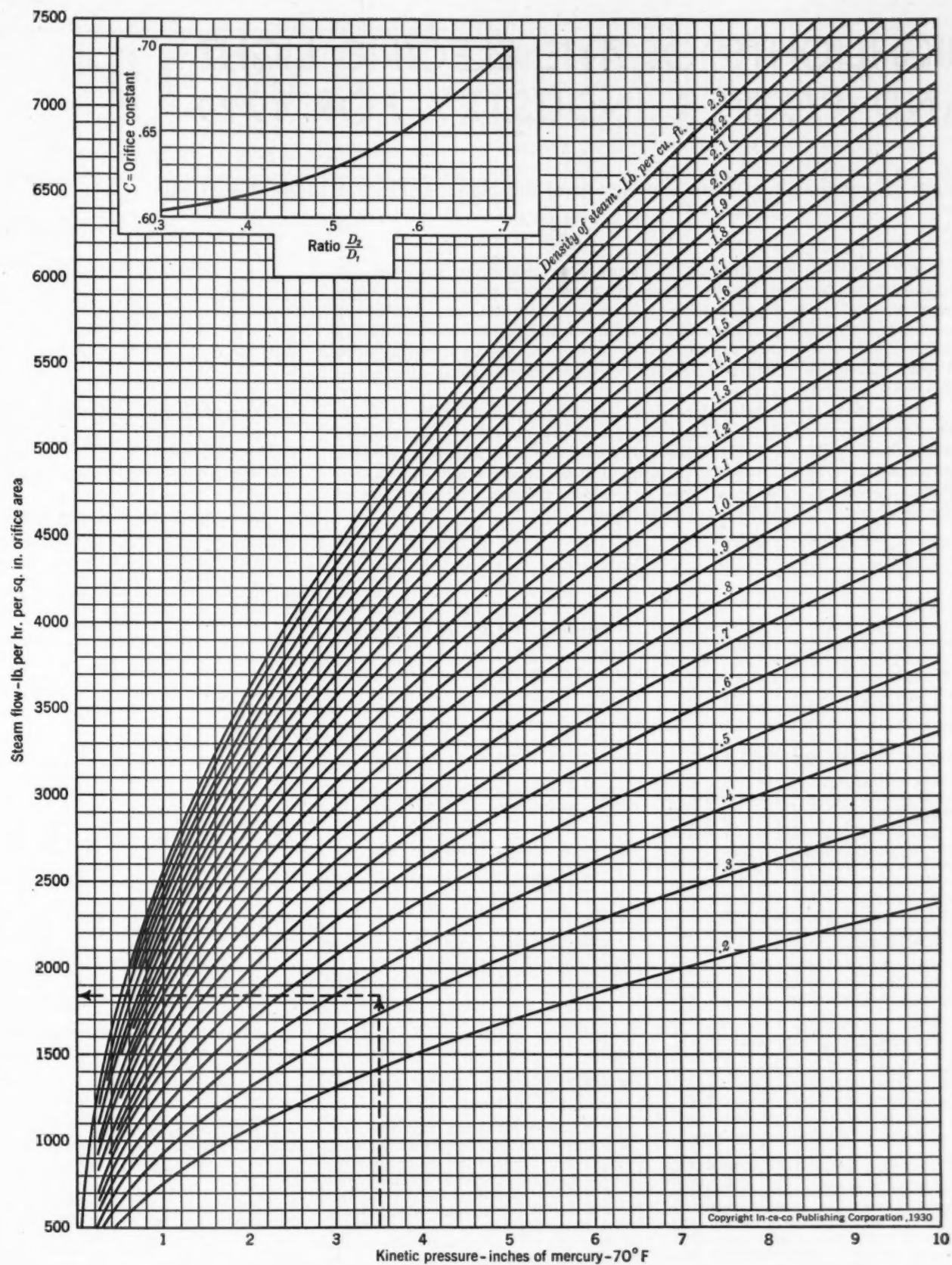


CHART FOR DETERMINING STEAM QUANTITIES

No. 13 of a series of charts for the graphical solution of steam plant problems

HIGHLIGHTS OF THE ELECTRIC LIGHT AND POWER INDUSTRY FOR 1929

Salient Information from Statistical Report of the National Electric Light Association

The statistics presented on this page are taken from a report just issued by the National Electric Light Association and embrace the operations of enterprises devoted exclusively to the generation and distribution of electricity, plus the electric departments of all others which maintained electric light and power systems jointly with other public utility services. These "composite" companies constitute approximately three-quarters of the total number.

These data were determined from reports received at N. E. L. A. headquarters from some 400 companies, whose operations represented approximately 92 per cent of the entire industry and, together with the published returns of municipal systems and of others filed with various Public Service Commissions, were pro-rated to cover 100 per cent of the total electric light and power business.

The year 1929 was one of outstanding growth in the electric light and power industry. Electric service in all of its important phases expanded remarkably, as shown by statistics compiled from reports submitted by companies representing 85 per cent of the industry.

Electric Output Increased 11.8%

The generation of energy by public utility electric light and power plants increased by 9,491,000,000 kw-hr., or 11.8 per cent. The total output was practically 90,000,000,000 kw-hr., of which amount 59,000,000,000 or 66 per cent was furnished by fuels and 31,000,000,000 or 34 per cent was furnished by hydro-electric plants. The output from steam plants increased by 19.3 per cent while the output from hydro-electric plants showed a very slight decrease. The year 1929 was deficient in rainfall over a large part of the country, curtailing the output of hydro-electric plants and throwing more load on steam stations.

Fuel Efficiency Improved 4%

The efficiency of fuel-burning plants continued to improve, reducing the average rate of fuel consumption from the equivalent of 1.74 lb. of coal per kw-hr. in 1928 to 1.67 in 1929, a further improvement of 4 per cent.

Generating Capacity Increased 9%

The installed capacity of generating plant reached 29,558,000 kw., an increase of 2,440,000 kw. or 9 per cent. The new construction was divided approximately as follows: 2,200,000 kw. in steam plant, 160,000 kw. of hydro-electric plant, and 80,000 kw. in internal combustion plants.

The use made of generating capacity continued to improve. All generating plants taken together, the electric light and power industry operated an average of 34.8 per cent of capacity for the year as a whole as compared with 33.9 per cent in 1928 and 33.5 per cent in 1926. For the first time of record the average kw. of generator capacity was called upon to work more than 3000 hr. out of the 8760 hr. in a year.

Increase of 4.3% in Customers

All classes of customers increased in number by 1,000,000 or 4.3 per cent, making a total at the end of 1929 of a little over 24,000,000. The number of domestic consumers reached approximately 20,000,000, an increase of 900,000, or 4.6 per cent. The estimated total number of homes in the United States at the end of 1929 was 29,000,000 and the proportion served by electricity was thus 68 per cent as compared with 66 per cent a year earlier.

Farms Served Increased 21.6%

Farm customers as of Dec. 31, 1929, numbered 560,000. This was an increase for the year of approximately 100,000 farms or 21.6 per cent.

In many states, farm electrification has already reached very considerable proportions. The rate of increase in some states is remarkable. For the entire country, 8.8 per cent of the farms are now served by central station power. In the states of California, Washington and Utah, one-half of the farms are so served.

Revenues Increased 8.9%; Electricity to Customers 12.1%

Revenue from all classes of consumers totaled \$1,955,325,000, an increase of \$159,050,000 or 8.9 per cent over the previous year. The increase in revenue of \$159,050,000 compares with an increase of \$133,757,000, or 8 per cent, for the previous year. This increase of 8.9 per cent, compared with an increase of 12.1 per cent in the total kw-hr. sales to ultimate consumers, furnishes a measure of the reduction in average prices.

Revenue from the sale of current to all classes of customers grew at a somewhat lesser rate than the output of energy, reflecting in part the high level of business activity of the past few years and the greater utilization of industrial power, and, to a larger degree, showing the results of the industry's general policy of reducing rates and thus passing on to the public the benefits accruing from the economies of improved engineering and management.

Price of Electricity Reduced 3%

The average revenue per kw-hr. sold for all classes of customers was 2.58c. as compared with 2.66c. of the year before, a decrease of 3 per cent.

Domestic Rate Reduced 5.7%

The average price of current to the domestic consumer dropped from 6.55c. per kw-hr. to 6.18c., a reduction of .37c. or 5.7 per cent. At the same time the average consumer increased his use of current from 459 kw-hr. per annum to 502 kw-hr. per annum, an increase of 43 kw-hr. The average annual bill per customer increased from \$30.10 in 1928 to \$31.02. Thus, the average annual use of current by the domestic consumer increased 9.4 per cent and his average annual bill increased 3.1 per cent.

This reduction of .37c. per kw-hr. sold to the domestic consumer, multiplied by the total sales to domestic consumers of 9,804,000,000 kw-hr., represented a total saving to domestic customers of over \$36,000,000.

Construction Expenditures Up 13%

New construction expenditures for the electric light and power industry were \$853,000,000, an increase of 13 per cent over like construction expenditures in 1928. This expenditure was \$53,000,000 in excess of the total budget as reported at the beginning of 1929. The budget for the year 1930, as reported, totaled just over \$1,000,000,000. This amount is 15 per cent greater than preliminary estimates had indicated.

The 1930 budget shows 30 per cent devoted to generating facilities; 32.5 per cent for transmission lines and substations, and 28.5 per cent for the distribution system. The remaining 9 per cent went to office buildings, service buildings and other miscellaneous uses. The \$298,000,000 for power plant construction is divided: 84 per cent for steam generating stations, and 16 per cent for hydro generating stations.

It is worthy of note that the increase of 13 per cent in new construction for 1929 over 1928 corresponds very closely with the increase in sales to ultimate consumers of 12.1 per cent.

Additional Transmission Lines

Transmission line construction proceeded at about the normal rate. There were built 10,955 circuit miles of lines at 11,000 volts or above, making the total at the end of the year about 160,000 miles. In the previous year 11,009 miles were built and in the year before that 17,200 miles were built. The new budget shows still greater expenditures proposed for 1930 for building transmission lines.

NEWS

Pertinent Items of Men and Affairs

1000 Mile Natural Gas Line Contracts Awarded

The Continental Construction Company, at its Kansas City, Mo., office, has awarded contracts for the construction of the 1000-mile natural gas pipe line to extend from the Texas Panhandle to Chicago, to the engineering firms of Ford, Bacon & Davis, Inc., New York; Smith Bros., Dallas; Bechtel & Kaiser, San Francisco, and Sheehan Bros., of Tulsa, Okla.

This natural gas line, estimated to cost \$100,000,000, was projected by a group of utility and petroleum interests consisting of the Cities Service Company, Insul & Son, Southwestern Development Co., Standard Oil Co., of New Jersey, Texas Corporation, Skelly Oil, Phillips Petroleum and Columbian Carbon, which formed the Continental Construction Company to construct the line.

The line will be supplied by the large gas reserves of these companies in Texas, Oklahoma and Kansas, which exceed 7,000,000,000,000 cubic feet. It is planned to serve more than fifty cities and towns along the projected route.

American Arch Company, New York, announces the removal of its main offices from 17 East 42nd Street to 60 East 42nd Street, New York.

The Iron Fireman Manufacturing Company, manufacturers of small stokers, has announced that its sales for the first six months of this year showed a gain of 27 per cent over the corresponding period of 1929 and a gain of 84 per cent over the first half of 1928.

Howard H. Bristol was recently elected to succeed his uncle, the late Professor William H. Bristol, as president of the Bristol Company, manufacturers of recording instruments. Carlton W. Bristol was named first vice-president; H. L. Briggs, second vice-president; S. R. Bristol, secretary and treasurer, and Harris Whittemore jr., assistant treasurer.

The Davis Regulator Company, formerly known as the G. M. Davis Regulator Company, recently moved into its new factory located at 2541 South Washtenaw Ave., Chicago. Erection of the new plant was made necessary by the expansion of manufacturing departments to increase production facilities.

Report \$18,000,000 Order for Koppers

The Koppers Company of Pittsburgh has been awarded an \$18,000,000 order for 456 coke ovens, to be divided into eight batteries of fifty-seven ovens, by the Russian Soviet Government, according to a recent press report.

It is believed that this contract represents the largest single order ever placed for coke ovens.

The ovens will be installed in a plant in Russia now being built under the direction of Arthur McKee, Cleveland engineer, the report further states. The cost of the completed plant is announced as \$225,000,000.

International Filter Co. and associated companies, International Water Softener Co. and General Zeolite Co., announce that expansion of their manufacturing facilities required the removal of their General Offices and Engineering Departments from Plant No. 1 at 333 West 25th Place, Chicago to larger quarters on the 13th and 14th floors of the Buckingham Building, 59 East Van Buren Street, Chicago.

Edge Moor Iron Company, boiler manufacturers, Edge Moor, Del., announces the appointment of Harry L. Moody as general sales manager. Mr. Moody was formerly sales manager of the U.G.I. Contracting Company of Philadelphia.

Jenkins Bros., New York, manufacturers of valves, has announced the election of James R. White as a vice-President, and his appointment as director of sales.

The Superheater Company has moved its Chicago office to 1325 Peoples Gas Building, 122 South Michigan Boulevard, Chicago.

The Terry Steam Turbine Company announces the appointment of John J. Somes as manager of the Chicago office. The new location of this district office is Room 556, 20 North Wacker Drive Building, Chicago.

The Swindell-Dressler Corporation, Pittsburgh, manufacturers of furnaces and combustion equipment has been joined by Gas Combustion Company and Duquesne Burner Service Company. The other organizations in the consolidation are William Swindell & Brothers and American Dressler Tunnel Kilns, Inc. The address of the company is P.O. Box 1753, Pittsburgh.

The officers of the new corporation are, John F. Casey, President; Philip Dressler, Ralph W. Porter, Frank W. Brooke and William H. Cosgrove, Vice-presidents; Samuel B. Casey, Treasurer; R. E. Whitaker, Secretary.

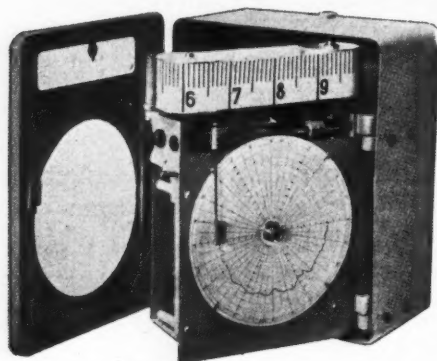
NEW EQUIPMENT

of interest to steam plant Engineers

A New Pyrometer

A very novel instrument for measuring and recording temperature has recently been developed by the Uehling Instrument Company, 4 Vesper St., Paterson, N. J. This instrument, which is known as the "Self-Contact" Potentiometer Pyrometer was primarily designed for measuring high temperatures as experienced in the iron, steel and ceramic industries. It lends itself equally well, however, to the measuring and recording of any temperatures where a high degree of accuracy is desired. Either a thermo-couple or an electric resistance bulb may be used as the temperature element.

The "Self-Contact" Potentiometer Pyrometer entirely eliminates the use of depressor



bars, cam mechanisms, and continuously operating motors. This is made possible by a unique design which assures definite and reliable contact between the needle of a galvanometer and stationary contact pieces, without in any way employing auxiliary mechanical devices which in one way or another conflict with the indicating needle.

Although the "Self-Contact" Recorder retains all the advantages of the potentiometer, the novel contact method permits placing the galvanometer apart, and at almost any distance from the recorder. This makes possible a very simple and rugged recorder construction that will withstand rough plant conditions and abuses, in a way that is impossible when the galvanometer forms part of the recording mechanism.

The Recorder is actuated by a galvanometer that may be placed in any desired location, quite apart from the recorder. A single galvanometer will actuate as many as four Recorders, each Recorder in a different location, each measuring a different temperature, and if desired, each having an entirely different calibration.

The entire recording mechanism is fastened to a frame which is hinged to the case as shown in the accompanying illustration. Everything may therefore be opened up to permit accessibility to all parts of the apparatus. A small motor operates only as and when necessary to adjust the pen to the proper temperature reading on a clock driven chart. It is also in geared connection with two pulleys over which a translucent endless belt, about 2 ft. long, is placed. The belt is calibrated in temperature units and will move in direct proportion to the pen mechanism

but at a greater speed. This permits a very open and legible scale which moves in back of a pointer fastened to the door. The legibility of the figures, the exceptional length of the scale, and the fact that it is illuminated from the rear, make it very easily read under all conditions at a distance of 75 ft. or more. This is a very important feature which, due to the fact that the galvanometer does not form part of the recording mechanism, permits placing the recorder where it will most assist the operating staff.

Dust Handling System

THE Hydrovac System of Dust Removal has been announced by The Allen Sherman-Hoff Company, Philadelphia.

This system was designed for handling the fly ash that accumulates behind the last pass of boilers, beneath economizers and air preheaters and in breechings and dust collectors. It may also be used for removing the siftings from beneath stokers.

In the Hydrovac System, dust and soot are removed in dry condition through a Wind Swept Valve, the dust being thoroughly mixed with water and discharged by means of an A-S-H "Coghlan Type" Hydrovactor.

The Wind Swept Valve is bolted to the bottom of the dust collection hopper, the dust piling in the body of the valve. Ports are located on each side of the valve, one being connected to the suction line leading to the Hydrovactor, and the other serves as an air inlet.

When the valve is not in operation, both ports are sealed by means of a rotary valve, which extends through the body, thus preventing the infiltration of air through the unit to the dust collection hopper.

When dust is to be removed, the rotary valve unit is turned 90 degrees by means of an operating lever at the air inlet end of the valve. This rotary valve has hollow ends, and when rotated, openings in the side of the cylinder coincide with the inlet and discharge ports.

The A-S-H "Coghlan Type" Hydrovactor consists of a ring of water nozzles fed from a circular header. High velocity water streams from these nozzles converge in the Hydrovactor. This action entrains the dust

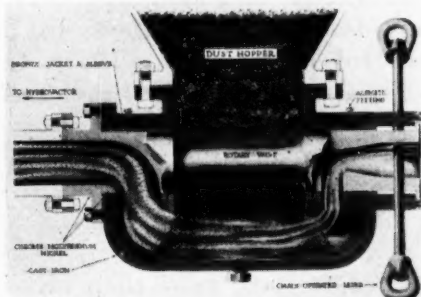
laden air, producing a vacuum in the suction line between the Wind Swept Valve and the Hydrovactor. Air enters the open port of the valve, is pulled through the pile of dust in the valve, thus carrying the dust particles through the discharge port and suction line to the Hydrovactor. The water in the Hydrovactor thoroughly mixes with the dust particles and the dust laden water leaving the Hydrovactor passes through a discharge line to disposal. Since the vacuum produced in the Wind Swept Valve is in direct proportion to the quantity and velocity of the water in the Hydrovactor, it is impossible to overload or jam the system.

Several A-S-H Wind Swept Valves can be connected to a common suction line served by one A-S-H "Coghlan Type" Hydrovactor, only one valve being operated at a time.

The Hydrovac is a totally enclosed, dust and water-tight system, assuring cleanliness in the removal and disposal of dust.

Air under vacuum is the most effective dust feeding agent but water is the logical dust conveying medium, for it completely imprisons each dust particle and prevents its escape.

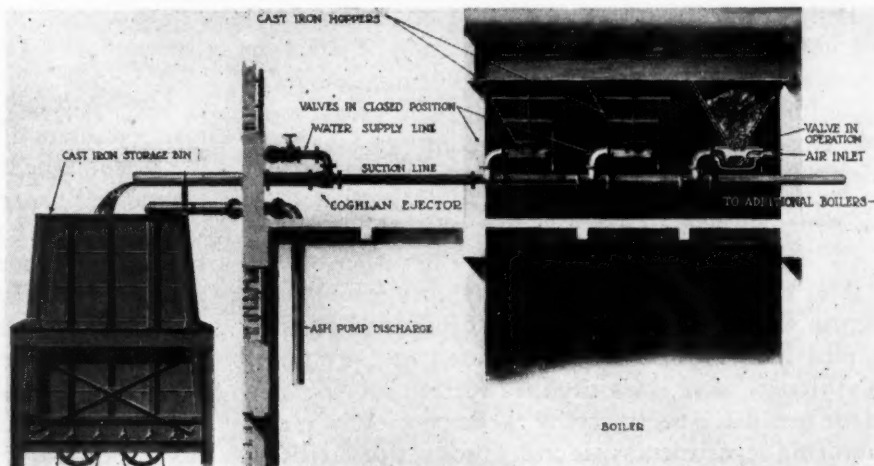
For successful operation, it is essential that the dust be thoroughly emulsified with the water to prevent its being carried in the



form of partly dry globules. This action is positive with the Hydrovactor, for the volume and velocity of the conveying water regulates the vacuum which feeds the dust.

The operation of the Hydrovac System is entirely automatic, and not dependent on any manual or mechanical regulation to control the flow of material. Dust will not leave the hopper until there is sufficient hydraulic power to carry it to disposal and likewise if the water supply varies, the feeding of dust also varies. The operation of the system is therefore fool proof, and damming of the system is impossible. The operator simply turns water into the Hydrovactor and opens one Wind Swept Valve at a time.

Another advantage of conveying dust to disposal mixed with water is that after the water drains off, the dust is sufficiently wetted down to prevent its blowing away.



DO YOUR BOILERS PRIME?

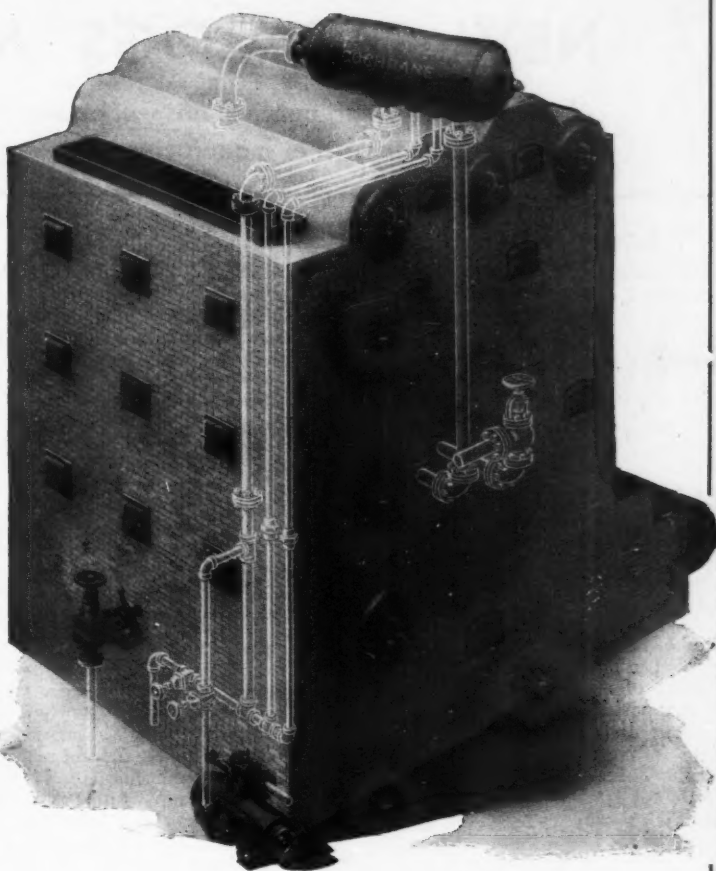
WET STEAM from priming boilers carries solids in solution or suspension in the boiler water. These impurities are harmful because they

Choke up the superheater, with resulting burning out of tubes and loss of superheat.

Cause sticking of turbine governor valves, which may result in over-speeding and wrecking.

Wear turbine blades, reducing efficiency, and clog turbine passages, reducing efficiency still more.

No matter how much water or sludge is present or whether the boilers are forced 100%, 200%, 300% of rating—you can count on effective elimination from the



Cochrane Steam Purifier

Its efficiency is EXTRAORDINARY!

This steam Purifier is continually cleansed by the water separated from the steam and does not fill up and cause excessive pressure drop. It never requires cleaning, and it is external to the boiler steam drum, leaving the full capacity of the latter available for the accommodation of variations in water level.

It is of construction similar to, and will last as long as, the boiler.

It stops the heaviest slugs of water.

Ask for Bulletin IC-677

COCHRANE CORPORATION

3160 North 17th St., Philadelphia, Pa.

NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Boiler Blowdown System

The Henszey continuous Blowdown System is described in a new bulletin. This system provides a method of deconcentration which consists of withdrawing or blowing off the concentrated impure water from the boiler and substituting fresh water, at the same time transferring the heat from this blowoff to the feed water. With soft water, the deconcentrator alone is usually sufficient to insure a clean boiler. With hard water, the deconcentrator is used in conjunction with a water softener plant. A four color chart shows the application of the system. 12 pages, 8½ x 11—Henszey De-Concentrator Company, Watertown, Wis.

Burners for Oil Stills

Peabody Burners for firing Oil Stills are presented in new Bulletin No. 501. The high capacities of modern oil stills place them in the same position to take advantage of the use of forced draft as the modern boiler plant. While forced draft burners and mechanical atomization are recommended, provision may be made for natural draft and for steam atomization, if desired. 20 pages and cover, 8½ x 11—Peabody Engineering Corporation, 40 East 41st Street, New York.

Centrifugal Pumps

The second of a series of "Centrifugal Pump Selection Chart Bulletins" has just been issued as Bulletin No. 201. This second book covers multi-stage pumps for capacities up to 2000 gal. per min. and heads up to 2400 feet. As with the first book, a comprehensive group of charts enables the prospective pump user to quickly and easily determine just what pump is best suited to his individual requirements. Complete description, including cross sections, bearing details and dimensions for each pump follow. 32 pages and cover, 8½ x 11—Goulds Pumps, Inc., Seneca Falls, N. Y.

Cork—Industrial Applications

The principal characteristics of cork are: heat insulating property, buoyancy, compressibility, frictional property and ability to resist liquid penetration. A new booklet "Industrial Applications of Cork," describes these characteristics and points out hundreds of uses for cork and cork compounds in engineering and industrial work. Due to its resiliency, cork is widely used to deaden the noise and vibration of machinery. 48 pages and cover, 6 x 9—Armstrong Cork Co., Lancaster, Pa.

Dust Handling System

A new bulletin presents the Hydrovac System for handling fly ash from behind the back pass of boilers, beneath economizers and air preheaters and in breechings and dust collectors, also for removing siftings from beneath stokers. The system comprises manually operated dust valves located under each dust hopper and connected to a conveyor pipe which has a ring of water nozzles near the discharge end. The high velocity water streams produce a vacuum in the system and when a dust valve is opened, the dust is drawn into the conveyor and carried through the water streams where it is entrained in the water and discharged. 8 pages, 8½ x 11—Allen-Sherman-Hoff Co., Philadelphia.

Economizer

The C-E Economizer of the Fin-tube type is comprehensively described in a new catalog EC-1. This economizer introduces a new design of tube arrangement which, combined with the extended surface in the form of fins on the tubes, results in a very compact and efficient unit. Some of the unique features incorporated in this new economizer are the alternate internal and external return bends, the two separate water circuits which materially reduce the water pressure drop and a design of the end plates which permits their being quickly and easily removed for cleaning and inspecting the tubes. 12 pages and cover, 8½ x 11—Combustion Engineering Corporation, 200 Madison Avenue, New York.

Evaporators

Griscom-Russell Evaporators for distilling boiler feed make-up water are described in a new bulletin No. 361. The Reducing Valve Evaporator System, a recent development, is presented for the first time. This system is particularly applicable to industrial plants which require steam for process work and to plants requiring a high percentage of boiler-feed make-up. The functions, application arrangements and advantages of evaporators are presented and many illustrations and charts are included. 36 pages, 8½ x 11—The Griscom-Russell Co., 285 Madison Ave., New York.

Feed Water Analysis

L & N Notebook No. 3, "Notes on Hydrogen Ion Measurements" has just been issued. The specific purpose of this publication is to furnish information that will be helpful to the large and rapidly increasing number of engineers who are interested in measuring the acidity and alkalinity of water solutions by electrical methods. Fundamental principles are briefly discussed and the apparatus and its use are carefully described. 48 pages and cover, 5½ x 7¾—Leeds & Northrup Co., 4901 Stenton Avenue, Philadelphia, Pa.

Fire Box Boilers

Bulletin 2000 describes Pierce Firebox Boilers suitable for pressures up to 15 pounds. The boilers are of riveted construction and are built to A.S.M.E. requirements. Tables are included to present setting dimensions covering both plain furnace types and down draft furnace types, each of which is available in 20 sizes. 4 pages, 8½ x 11—Ames Iron Works division of Pierce, Butler & Pierce Mfg. Corp., Oswego, N. Y.

Furnace Refractories

A new folder describes "ESENCO" furnace construction and refractories. Air cooled blocks are shown of a design which is applicable to the building of hollow air-cooled furnace walls. These blocks are available in a number of refractories, such as Silicon Carbide, Fire Clay, and Aluminum Oxide, possessing a wide range of characteristics. Silicon carbide is recommended because of its ability to withstand heavy load stresses at high temperatures and because of its high rate of heat transfer. 6 pages, 8½ x 11—Essex Engineering Company, Belleville, N. J.

Heat Exchangers for Liquids

Schutte and Koerting Heat Exchangers for Liquids are described in a new two-color Bulletin No. 12-H. In many industrial processes certain liquids must be heated while other liquids must be cooled. A convenient means of accomplishing both results is the surface type combination heater and cooler, designated as a "heat exchanger." Single unit, Two-unit and Multiple-unit types are illustrated and described. A chart shows the performance of a typical heat exchanger. 8 pages, 8½ x 11—Schutte and Koerting Co., Philadelphia.

Refractory Arches

The Liptak Double Suspension Arch is featured in a new Catalog No. 17. As indicated by its name, this construction is really two arches in one—a fire arch that is exposed to the fire and which is suspended from a reserve arch above. The lower arch is replaceable when necessary, while the upper arch is permanent. Photographs show details of construction while line drawings show various application arrangements. 20 pages and cover, 8½ x 11—Bigelow-Liptak Corp., Detroit.

Steam Turbines

Murray Steam Turbines for pump and auxiliary drives, are illustrated and described in bulletin T 106. For boiler feed pump drives, three separate governing devices are recommended: (1) an excess pressure governor which normally controls the unit and which is operated by the differential between the pump discharge pressure and the boiler pressure, (2) a constant speed governor set high so as to function at the highest speeds, (3) an emergency governor, set about 10 per cent above the constant speed governor, and which would come into action in case the other governors fail to function. Details of construction are shown. 8 pages, 8½ x 11—Murray Iron Works Company, Burlington, Iowa.

White Interior Paint

Newlite Interior White provides a smooth finish of great durability and exceptional light reflecting value. It is used extensively in industrial plants, public utilities and railroads. Newlite reflects from 70 to 75 per cent of the light that strikes it, increasing the illumination from 20 to 45 per cent. A bulletin describing this paint and its application, is available. 12 pages, 7¾ x 10¾—Cheesman-Elliott Company, 639 Kent Avenue, Brooklyn, N. Y.

NOTICE

Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to

COMBUSTION
200 Madison Ave., New York

Use of Chlorine Gas to Prevent Aquatic Growths on Condenser Tubes

(Continued from page 46)

treated every three weeks from April to October, since mussels grow much more rapidly in summer. Possibilities of a partial remedy are also represented by the fact that with a velocity in the water over 6 ft. per second mussels find it very difficult to attach themselves to pipes or other objects.

Another method is to use copper sulphate solution as a poison. This method has been used since 1913 by the Cargo Fleet Iron Company Ltd, of Middlesbrough on the North East Coast, to fight the trouble of mussel spawn growing in the salt water main. For this purpose, small pipes are inserted at different points in the main pipe and periodical doses of strong copper sulphate solution are given, equal to about 1 pint per 10,000 of the water, so as to kill or damage the spawn and cause it to loosen its hold. Also at intervals cop-

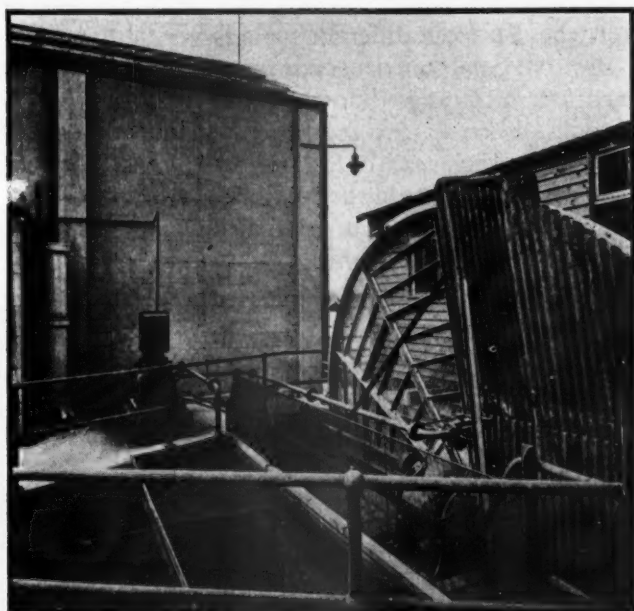


Fig. 5—Another view of Chloronome installation at Hackney Station showing absorption tower and intake screen for cooling water

per sulphate crystals are dissolved in the salt water tank so as to pass through the whole pipe circuit. It is stated this copper sulphate method was recommended to another large firm that had to install a complete new 30 in. water main 3000 ft. in length to duplicate a similar main almost completely choked with mussels, representing many tons of material.

There seems to be no question, however, and especially in connection with power stations, that chlorine gas is the ideal means of preventing all forms of aquatic growths. Chlorine gas is a 100 per cent pure product which cannot vary in composition and which, therefore, lends itself readily to simple and dependable control. Furthermore, it is claimed that in no case has any harmful result been experienced with pumps, mains, condenser tubes, or any other part of the station equipment chlorine gas treatment.

Certified FACTS Build Sales

Granted that you manufacture and sell a product of superior merit—how can you best convince your trade of this fact—how can you fortify your salesmen against sales resistance of mere generalities and claims—how can you lift your product above the classifications of the ordinary?

Back the excellence of your product with scientific proof as certified by the Pittsburgh Testing Laboratory.

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product has been individually inspected and tested by us, and that this tag is affixed by our engineer as denoting approval in accordance with test requirements outlined on the reverse side of this certificate.



Pittsburgh Testing Laboratory
Pittsburgh, Pa.

The certificate to the left aided the Grimell Company of Providence, R. I., in establishing a new product.

PITTSBURGH
TESTING LABORATORY
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BRANCH OFFICES IN PRINCIPAL CITIES

Burning Characteristics of Solid Fuels

Bureau of Mines reports results of investigation of smokeless fuels

Interest in smokeless fuels has centered attention on the relative burning characteristics of cokes made by the various high- and low-temperature processes. Recently the Physical Chemistry Section of the Pittsburgh Experiment Station, United States Bureau of Mines, has published data on the time of burning of small particles of coal, semicoke, beehive coke, and charcoal under controllable conditions of furnace temperature, particle size and oxygen concentration.

Investigations along this line are being continued on somewhat larger particles and are also being extended to include still other fuels.

Through the use of fuel particles weighing 4 milligrams it has been possible to follow the temperature of the particle throughout its burning. The maximum temperature of an individual particle burning in an excess of air at 800 deg. cent. is, of course, much below the temperatures obtainable in a fuel bed.

The interesting part of the temperature curve of the burning, however, is the form the curve takes under different conditions. When the air temperature is 800 deg. cent. the rate of rise of the particle temperature above the air temperature is slow and variable so that it is nearly impossible to assign a

definite point as the "start" of ignition or active burning. Likewise, the point of completion of burning is often prolonged. With air at 1000 deg. cent. the rate of rise and decline of temperature is very rapid. These effects vary with the nature of the fuel, being most pronounced for a material like electrode carbon. Therefore, strict comparisons of the burning times of many fuels by this method at the lower air temperatures are not possible.

It has been suggested that, given a sufficiently high temperature, the rate of burning of various forms of carbon will depend only on the rate at which oxygen can reach the carbon surface. There is some evidence for this from the experimental side. If this is so, as far as the rate of disappearance of the carbon dioxide goes, attention is drawn away from the question of "reactivity" of the carbon in a fuel bed where normally the temperatures are fairly high. The reactivity of the carbon as far as reduction of carbon goes, may still be very important—likewise the nature and disposition of the ash. In fact, the ash from different fuels is very different.

Beehive coke under certain conditions produces a hard ash retaining almost the original size of the particle, whereas low temperature coke produces a fluffy ash which readily falls away from the particle. Covering of the unburned carbon by the ash from previous burning would seem to have an important effect on the rate of burning.



VISIBILITY

Tilted Scales

To the Ellison Pointer Draft Gage—Straight-Line Movement, known for accuracy and visibility, has recently been added the Tilted Scale type for mountings higher than eight feet. Made in three styles in from one to fifteen pointers.

ELLISON DRAFT GAGE COMPANY
214 West Kinzie Street Chicago



Flush Type
Projection $\frac{3}{16}$ "

Semi-Flush and
Wall Type



**MAKE
FUEL
WASTE
VISIBLE**

with

**A P E X
CO₂ RECORDERS**

Send for Catalog

UEHLING INSTRUMENT CO.
4 Vesper St. Paterson, N. J.



CO₂ Recorders
in Office of Chief Engineer
registers every change in
furnace condition.

CO₂ Indicator for boiler
front guides the fireman
in saving coal

American Boiler Manufacturers Association

At the annual meeting held recently at Sky Top Lodge, Sky Top, Pa., the American Boiler Manufacturers Association elected the following officers for the ensuing year:

President, H. H. Clemens, Erie City Iron Works, Erie, Pa.; Vice-President, Owsley Brown, Springfield Boiler Company, Springfield, Ill.; Secretary and Treasurer, A. C. Baker, 801 Rockefeller Building, Cleveland, Ohio.

In addition to the officers, the executive committee of the association includes the following:

Homer Addams, Fitzgibbons Boiler Co., Inc.; Geo. W. Bach, Union Iron Works; Sidney Bradford, Edge Moor Iron Co.; F. W. Chipman, International Engineering Works; R. E. Dillon, Titusville Iron Works; E. G. Wein, E. Keeler Co.; C. E. Tudor, Tudor Boiler Mfg. Co.; A. C. Weigel, Combustion Engineering Corporation; H. E. Aldrich, The Wickes Boiler Co.

Stoker Manufacturers Association

At the annual meeting of the Stoker Manufacturers Association held recently at Philadelphia, the following new officers were elected:

President, Joseph G. Worker, American Engineering Company, Philadelphia; Vice-President, James F. Turner, Flynn & Emrich Company, Baltimore; Treasurer, F. H. Daniels, Riley Stoker Corporation, Worcester, Mass.; Secretary, William V. McAllister, Riley Stoker Corporation, Detroit.

Two additional companies were recently admitted to membership—Auburn Stoker Company, Auburn, Ind., and Combustioneer, Inc., Goshen, Ind., bringing the total of member companies to twelve.

The Fall meeting of the association has been tentatively scheduled for October 13, 14 and 15 at The Homestead, Hot Springs, Va.

Prize Contest for Use of Pulverized Fuel Ash

Prizes totalling 5,000 marks are to be awarded for the three best suggestions for the economical utilization of fly ash produced by pulverized coal firing. The suggestions must be received at the office of Reichskohlenrates, Berlin W. 15, Ludwigkirchplatz 3/4 not later than January 1, 1931.

So that the jury cannot identify the entrants, the name of the author must be omitted and each suggestion labeled with a code word only. A sealed envelope, marked with this code word and containing the name and address of the contestant, must be attached.

For further details of the contest, address Geschäftsführer der Technisch-Wirtschaftlichen Sachverständigenausschüsse des Reichskohlenrates, Berlin W. 15, Ludwigkirchplatz 3/4.

COMBUSTION—AUGUST 1930



3 SPECIAL REFRACTORY CEMENTS FOR POWER PLANTS

R & E #3000

You can't find a better cement for all-around service in boiler plants. R & E No. 3000 air-sets to full strength; retains its bond; makes brick dislodgement impossible, will not crumble. Unusual adhesiveness makes No. 3000 extremely efficient for hot or cold patching. Fine texture permits extremely thin joints which, together with its excellent bond, is a further safeguard against bricks "pulling out."

"MOLDIT"

We recommend Moldit for such work as monolithic floors, checker work and arches. It avoids delays in waiting for special tiles or brick. Just add a little fresh water and mold it into any desired shape. Moldit "air-sets" and attains full strength without heat. It does not shrink and meets the most severe requirements of modern construction. You can use Moldit under temperatures up to 3000° F. It's easy to use, too. Add a little fresh water and pour—no ramming, no hammering—just mold it. Weighs only 100 lbs. per cu. ft. molded. Shipped in convenient 100 lb. waterproofed bags.

"MOLDIT-A"

Use Moldit-A for service under temperatures between 200° F. and 2400° F. It works the same as "Moldit" and can be used for monolithic floors, baffles, doors, etc., any place where great structural strength is essential, or desired. Like other R & E Cements, Moldit-A air-sets and gains full strength without heat. It weighs approximately 100 lbs. per cubic foot and is shipped in 100 lb. handy waterproofed bags. Order a few bags on trial today.

These cements are guaranteed to perform exactly as we claim. Money refunded if you are not satisfied. Try them.

Refractory & Engineering Corporation
50 Church Street
New York, N. Y.

Warehouses in
Baltimore, Norfolk, Philadelphia, Pittsburgh, Boston, Chicago

BOOKS

of Current Interest to Engineers

ELECTRIC SYSTEM HANDBOOK

By C. H. Sanderson

1167 pages—Price \$5.00

This book answers the increasing demand for a handbook which will tell the story of the electric system as a whole, in logical sequence and in a simple form readily understandable by everyone whether he possess a technical education or not. It gives complete and authoritative information on every phase of the work—the fundamentals of electricity; generating, transforming and auxiliary equipment; central and sub-stations; power lines; design, construction, operation, repair and inspection. Higher mathematics is entirely omitted and all technical expressions are fully explained.

HEAT TRANSMISSION BY RADIATION, CONDUCTION AND CONVECTION

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Making Gas from Powdered Coal

Ohio State University and Battelle Memorial Institute to cooperate in developing White process of coal carbonization

IMPROVED methods for manufacturing gas are constantly sought. What is wanted is a high yield of good quality gas, free from objectionable impurities, and coke and other products of value and commercial importance. Coal carbonization is a fertile field of research.

A new method of gasifying coal has been proposed and tested on a laboratory scale by Prof. Alfred White of the University of Michigan. In this process the coal in a finely crushed or pulverized state is dropped through the hot retort. A study of the process in a full-size commercial retort has been in progress at the Engineering Experiment Station, Ohio State University, Columbus, Ohio, under the direction of Prof. D. J. Demorest. A number of tests have been made, but the work was suspended during the past year. Arrangements have now been made for the investigation to be continued to completion in co-operation with the Battelle Memorial Institute, Columbus, Ohio.

The complete gas plant of the Experiment Station, and fuel and power, will be furnished by the University. For its part of the co-operation, the Institute has assigned members of its technical staff to carry on the work, is furnishing the necessary labor, and is providing all the materials and special equipment that is required.

The effect of size of coal particles, the rates at which the coal may be fed into the retort, and the evolution of gas at various temperatures are the particular factors to be studied in this investigation. A series of experiments involving all these variables is expected to indicate the conditions under which gasification may be carried out most successfully.

The gas from this process of carbonization is less in quantity than from ordinary gasification, but richer in heat units. The coke is fluffy and granular; the problem of compressing it into solid masses or of grinding it for pulverized fuel is an additional inviting field of research.

One difficulty encountered in these tests has been the tendency of dust and fine coal particles to carry over from the retort with the gas and tar. To eliminate this trouble the Institute is installing at the gas plant its high tension electric dust-settling apparatus.

Representing the Battelle Memorial Institute in this investigation is Floyd B. Hobart, fuel chemist, who recently joined the Institute staff to work under the direction of Clyde E. Williams, assistant director. Mr. Hobart was identified with the Illinois Engineering Experiment Station from 1921 to 1927 as research assistant to Dr. S. W. Parr and from 1927 to 1929 was in charge of experiments of the Parr process of carbonization.

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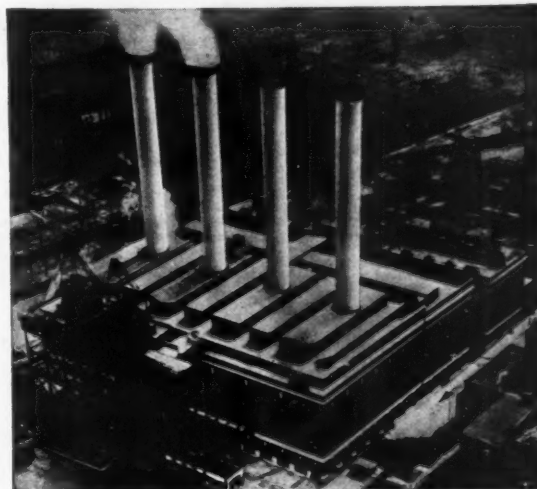
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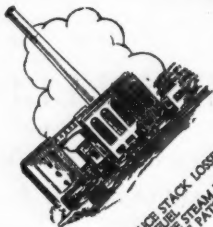
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Boiler, Stoker and Pulverized Fuel Equipment Sales

Total figures to June 1, as reported to the Department of
Commerce by the leading manufacturers in each industry

Boiler Sales

	Total 5 mo. 1930		Total 5 mo. 1929		May, 1929		May, 1930	
	No.	Sq. ft.	No.	Sq. ft.	No.	Sq. ft.	No.	Sq. ft.
Water tube	471	2,594,334	672	4,026,415	193	1,230,568	98	530,902
Horizontal return tubular	373	519,338	535	714,850	137	181,152	93	128,567

Mechanical Stoker Sales

Year and Month	TOTAL		TYPE OF BOILER			
			Fire-tube		Water-tube	
	No.	HP.	No.	HP.	No.	HP.
1929						
January...	97	43,392	36	5,835	61	36,557
February...	80	31,554	26	3,933	54	27,621
March...	117	42,432	42	6,369	75	36,063
April.....	141	48,749	41	6,508	100	42,241
May.....	174	60,772	64	9,951	110	50,821
Total (5 mos.)..	609	225,899	209	32,596	400	193,303
Total (year)....	1,716	599,585	706	102,515	1,010	497,070
1930						
January...	53	13,198	24	2,872	29	10,326
February...	73	22,648	26	3,732	47	18,916
March.....	*89	*32,403	45	6,128	*44	*26,275
April.....	*108	*35,903	*46	*6,984	62	28,919
May.....	96	31,956	41	5,703	55	26,253
Total (5 mos.)..	419	136,108	182	25,419	237	110,689

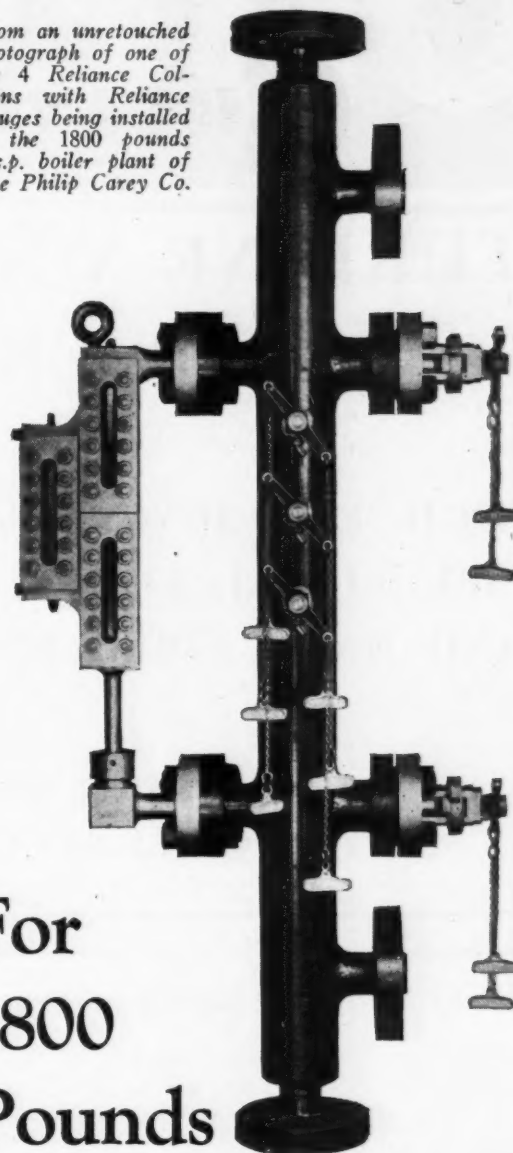
*Revised.

Pulverized Fuel Equipment Sales

Year and Month	CENTRAL SYSTEM			UNIT SYSTEM		
	No. of Pulver- izers	Total Rated capacity in tons of coal per hour	Total Rated hp. of boilers equipped	No. of Pulver- izers	Total Rated capacity in tons of coal per hour	Total Rated hp. of boilers equipped
1930						
January...	*1	6	1,600	52	*565	59,742
February...	2	20	3,000	29	*175	23,305
March.....	2	50	6,414	16	33	9,995
April.....	..	..	..	31	139	37,993
May.....	3	80	11,360	30	196	22,625
Total (5 mos.)..	8	156	22,374	158	1,108	153,660
FOR INSTALLATION UNDER WATER-TUBE BOILERS						
January...	..	..	..	6	35	965
February...	2	13	305
March.....	3	3	450
April.....	3	3	780
May.....
Total (5 mos.)..	14	54	2,500

*Revised.

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photograph of one of
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in the 1800 pounds
w.s.p. boiler plant of
The Philip Carey Co.



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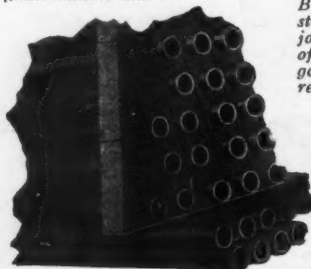
1. Auxiliary—We operate as an auxiliary to your own boiler room repair force.

2. Equipment—We are equipped to install BECO Baffles when you purchase new boilers or to rebaffle your old boilers regardless of size and number.

3. Economy—The use of BECO Baffle service will be more economical than expanding your present force who can be used to better advantage on other work.

4. Experience—Our experience of fifteen years in baffle wall work exclusively is at your service.

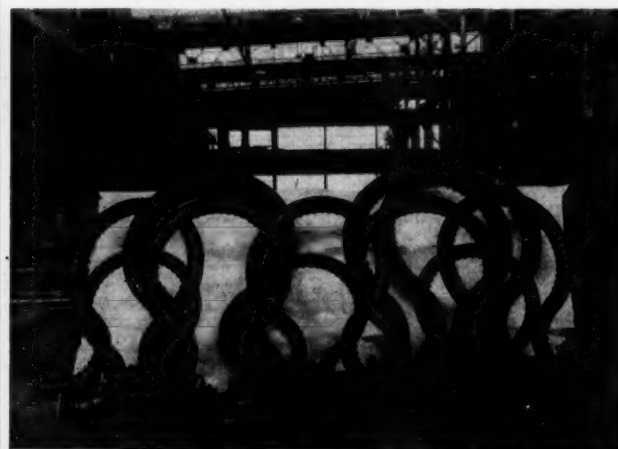
5. Engineering—Let us go over your baffle wall problems with you.



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